Gray Paper #1

Air Pollution & Environmental Inequity
in the San Francisco Bay Area

Ken Kloc, Ph.D., MPH

August 2011
CONTENTS

I. Introduction ........................................................................................................................................... 5

II. Bay Area Air Pollution Studies ............................................................................................................. 8

   1. BAAQMD’s CARE Program ..................................................................................................................... 8
   2. BAAQMD PM$\text{(_2)}$ Studies ................................................................................................................... 13
   3. BAAQMD’s Multi-Pollutant Evaluation Model ....................................................................................... 13
   4. ARB’s Neighborhood Assessment and SB 25 Activities ................................................................... 16
   5. AB 32 Related Activities ...................................................................................................................... 17
   6. Bay Area Diesel Pollution Studies ....................................................................................................... 19

III. Policies for Reducing Cumulative Air Pollution .............................................................................. 21

IV. Improving Cumulative Air Risk Reduction Programs ...................................................................... 23
Summary

Environmental justice advocates have long been concerned about the health impact of elevated air pollution levels found in disadvantaged communities across the country. Sustained public pressure on this issue has motivated regulators to initiate a variety of programs to better characterize the combined or “cumulative” air pollution exposure in localities with multiple pollution sources. In the last decade, local and state agencies have completed a number of relevant San Francisco Bay Area studies and the results are now being used to develop new pollution control policies. The goal of the present paper is to review this air quality research and the policies that have been proposed to deal with cumulative air pollution in the Bay Area.1

Much of the work has been carried out by the Bay Area Air Quality Management District (“BAAQMD”) and the California Air Resources Board (“ARB”). For example, BAAQMD evaluated the combined impact of toxic air contaminants and particulate matter (“PM”) from mobile, stationary, and area sources. It also modeled regional PM pollution and completed a risk/benefit analysis for ozone, air toxics, PM, and greenhouse gases. ARB published two Bay Area diesel PM assessments and analyzed hot spots and cumulative air exposures in conjunction with several of its statewide programs. Some cities have also made contributions. For instance, the City of San Francisco produced a diesel risk assessment for the Southeast portion of the city. Some findings that have emerged from these studies are: that mobile source pollution is the dominant air pollution issue regionally, that fine particulate matter (“PM$_{2.5}$”), including diesel particulate, produces the greatest level of health impact of any other form of air pollution, that air pollution hot spots occur throughout the Bay Area, and that numerous vulnerable communities are located in hot spot areas.

The agencies have begun to develop policies to address these cumulative pollution issues. For example, BAAQMD prioritized six areas in the region that have both elevated air pollution and vulnerable populations, and it has proposed several approaches to reducing air pollution on a more cumulative basis, such as multi-pollutant air quality planning and community risk reduction plans (“CRRPs”). With CRRPs, the air district is attempting to involve local land use agencies in a voluntary program to reduce cumulative air pollution arising from land use decisions. Currently, both San Francisco and San Jose are developing CRRPs for their cities. ARB has published land use guidelines and developed a variety of programs to reduce air emissions from shipping ports, rail yards, construction activities, and other activities associated with mobile source pollution.

Such initiatives are encouraging, but many community health advocates who want to reduce both cumulative risk and environmental inequity believe that more needs to be done. In order to make significant progress on these problems, new and more holistic methods of regulating air pollution need to be devised that will protect communities with vulnerabilities arising from exposure to multiple environmental stressors (chemical, physical, psycho-social, etc.). Although new legislation along these lines would facilitate matters, air quality agencies currently have the authority to make their programs “more cumulative” in a number of important ways.

1 Although beyond the scope of this paper, numerous studies and reviews on cumulative environmental risk and environmental justice have been published in the academic literature. For a recent review, see Morello-Frosch, R., Zuk, M., Jerrett, M., Shamasunder, B. and Kyle, A.D., “Understanding the Cumulative Impacts of Inequalities in Environmental Health: Implications for Policy,” Health Affairs, Vol. 30, No.5, 879-887, May 2011.
For example, some improvements that could be implemented by the local air district are:

- Develop better methods to characterize community health vulnerabilities and use these in regulatory decision-making related to air pollution;

- Adopt a broad definition of cumulative impacts, for example, the definition currently used by California Environmental Protection Agency (“Cal/EPA”);2

- Reduce PM pollution levels below both the federal PM$_{2.5}$ standard as well as the California PM standards (which include both PM$_{2.5}$ and PM$_{10}$), and address regulatory gaps related to point source primary PM pollution;

- Define additional small-scale cumulative impact areas and provide increased regulatory attention in these places;

- Take steps to reduce programmatic fragmentation, e.g., use cumulative risk methods to harmonize and unify the regulation of toxic and criteria air pollutants.

Local agency efforts to reduce cumulative air risk can be aided by appropriate measures at the state level. Cal/EPA, which has recently published a cumulative impact methodology document, should prioritize the development of more explicit guidance for all its divisions. In addition, ARB should promulgate statewide cumulative air risk regulations. Finally, city health departments and local land use agencies throughout the Bay Area need to become more involved in reducing cumulative air pollution by implementing strong CRRPs. Taking steps such as these, the various state and local agencies responsible for public health and welfare could significantly reduce the inequitable cumulative risk faced by disadvantaged communities in the San Francisco Bay Area.

---

2 Cal/EPA has recently proposed a cumulative impact evaluation methodology based upon a broad definition of cumulative environmental impact. This is further discussed below.
I. Introduction

Over the last two decades, environmental policy-makers have become increasingly concerned with the health risk from combined exposure to multiple forms of air pollution, and more generally, with the cumulative risk of exposure to all kinds of hazardous agents and detrimental living conditions. This heightened awareness has been sparked by environmental justice advocates who have argued that traditional environmental protection approaches ignore such risks and that disadvantaged communities bear an increased burden from them. In the case of air pollution, the burden is due to hot spots produced by the geographic concentration of pollution sources like busy highways and industrial facilities, or in some cases by a single insufficiently controlled source. A further issue is that communities with higher air pollution levels are more likely to be exposed to other unhealthy living conditions (e.g., poor quality housing, excessive noise, and lack of parks) causing increased vulnerability to disease. Air pollution hot spots, cumulative risk, and environmental justice are thus frequently linked together in environmental policy discussions.

Health agencies began paying more attention to cumulative risk in the 1990s in tandem with the rise of the environmental justice movement. In that period, for example, the U.S. Environmental Protection Agency (“EPA”) initiated a variety of cumulative risk projects. Over the years, EPA also published several cumulative risk methodology documents describing the basic differences between traditional and cumulative risk approaches (See Table 1 and Figure 1), defining key cumulative risk terms, identifying useful assessment methods, and discussing various other technical issues.3,4 In addition, EPA has produced various cumulative exposure tools and funded a number of community-based risk studies. It is currently developing a plan to incorporate environmental justice and cumulative risk concerns into agency policies and regulations.5

State agencies have also been active.6 For instance, Cal/EPA was designated in 2000 as California’s lead agency on environmental justice. It convened several stakeholder panels on environmental justice, adopted a broad definition of cumulative impact, and published a cumulative risk framework document as a resource for the agency’s boards, departments, and offices. The framework defines cumulative impacts as those arising from “exposures, public health or environmental effects from the combined emissions and discharges, in a geographic area, including environmental pollution from all sources, whether single or multi-media, routinely, accidentally, or otherwise released. Impacts will take into account sensitive populations and socio-economic factors, where applicable, and to the extent data are available.”7 The Cal/EPA framework describes methods for assessing and ranking communities in terms of relative cumulative impact. The approach recommends using a variety of direct and indirect environmental exposure measures, including exposure surrogates such as the prevalence of asthma.

---

4 EPA Risk Assessment Forum, “Framework for Cumulative Risk Assessment,” May, 2003. The framework defines cumulative risk as, “the combined risks from aggregate exposures to multiple agents or stressors.” Aggregate exposure is the total exposure to a stressor by “relevant routes, pathways, and sources.” Stressors are chemical, biological or physical agents, or activities that cause the loss of a necessity. (http://www.epa.gov/raf/publications/pdfs/frmwrk_cum_risk_assmnt.pdf)
6 This review focuses on California, and particularly on air quality studies relevant to the San Francisco Bay Area. However, other states have also been working on these issues. For an example from the state of New Jersey, see the March 2009 report, “Strategies for Addressing Cumulative Impacts in Environmental Justice Communities,” (http://www.nj.gov/dep/ej/docs/ejac_impacts_report_mauriello_response200908.pdf).
Table 1

Transition Toward a Cumulative Approach in EPA Risk Assessments*

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Endpoint</td>
<td>Multiple Endpoints</td>
<td></td>
</tr>
<tr>
<td>Single Source</td>
<td>Multiple Sources</td>
<td></td>
</tr>
<tr>
<td>Single Pathway</td>
<td>Multiple Pathways</td>
<td></td>
</tr>
<tr>
<td>Single Route of Exposure</td>
<td>Multiple Routes of Exposure</td>
<td></td>
</tr>
<tr>
<td>Central Decision-making</td>
<td>Community-based Decision-making</td>
<td></td>
</tr>
<tr>
<td>Command and Control</td>
<td>Flexibility in Achieving Goals</td>
<td></td>
</tr>
<tr>
<td>One-Size-Fits-All Response</td>
<td>Case-Specific Responses</td>
<td></td>
</tr>
<tr>
<td>Single Media-focused</td>
<td>Multi-media Focused</td>
<td></td>
</tr>
<tr>
<td>Single Stressor Risk Reduction</td>
<td>Holistic Reduction of Risk</td>
<td></td>
</tr>
</tbody>
</table>

* From: EPA Cumulative Risk Guideline (supra Footnote 3).

Figure 1

Community-Centered Approach to Environmental Risk*

* From: EPA Cumulative Risk Framework (supra Footnote 4).
Population characteristics that imply greater vulnerability to environmental stressors (e.g., socioeconomic status, racial demography, and age) are also considered. According to Cal/EPA, the method is designed as a screening tool for prioritizing policy initiatives.

California’s air quality agencies, for their part, have been working to address the specific problem of cumulative air pollution exposure. Although the traditional, “non-cumulative” air pollution programs have had some success in addressing a variety of air quality problems, they have not generally considered cumulative risk. Current state and federal law divides the air pollution problem into a number of pieces, each to be addressed separately by various regulatory agencies. Consequently, there are programs to control different categories of pollutants, such as the Criteria Air Pollutants (“CAPs”) and the Toxic Air Contaminants (“TACs”), and there are programs that focus on different types of pollution sources, such as stationary sources and mobile sources. This compartmentalized, non-holistic approach has a number of shortcomings.

For example, California’s Toxics Air Hot Spot law requires an air polluting facility to estimate the combined risk from its TAC emissions, but ignores the added health impact of its CAP emissions. Risk assessments under this law also disregard the additional risk from other nearby sources. Although acceptable exposure criteria for individual TACs are set to protect biologically sensitive members of the population, other community vulnerabilities are not considered when regulating TAC pollution sources. In the CAP program, only larger and newer facilities (or equipment) are evaluated for their impact upon air quality, and this is done on the basis of the individual pollutant, not by looking at the combined impact of all the facility’s air emissions. The California Environmental Quality Act (“CEQA”), which atypically includes requirements to evaluate the cumulative impacts of new projects, has been too narrow in scope and too limited in regulatory power to prevent the buildup of cumulative risk hot spots. Traditional mobile source programs have also failed to solve cumulative pollution issues arising from broader land use and transportation planning decisions.

This paper surveys some of the recent and more significant government research and policy efforts on cumulative air pollution in the San Francisco Bay Area of California. The two agencies that have done the most work on this topic are BAAQMD and ARB, either independently or in collaboration with others. Some related work by the City of San Francisco will also be discussed. The main purpose of this review is not to provide a detailed critique of the analytical methods or accuracy of any particular study, but instead to give the reader an overview of the regulatory response to the problem, and to identify gaps in existing programs.

---

8 For instance, BAAQMD and ARB regulations have decreased concentrations of ozone and several air toxics, such as chlorinated solvents, benzene, and 1,3-butadiene. In addition, ARB’s Diesel Reduction Plan is expected to reduce 2000 diesel PM emissions 85 percent by 2020, and BAAQMD has begun revising its PM regulations in order to decrease PM$_{2.5}$ concentrations.

9 The CAPs are: particulate matter, nitrogen dioxide, sulfur dioxide, ozone, and lead. The TACs are a list of more than 200 substances and mixtures originally defined in the California Health and Safety Code; the federal Clean Air Act defines a list of “hazardous air pollutants” that is similar to the TAC list.

10 This is less of an issue for CAPs such as PM and ozone, whose concentration limits are based on effects resulting from exposure of the general population (including vulnerable groups) to a pollutant in the presence of other commonly experienced health stressors.
II. Bay Area Air Pollution Studies

This section first reviews information developed by BAAQMD in its Community Air Risk Evaluation (“CARE”) program, the air district’s PM$_{2.5}$ modeling studies, and its Multi-Pollutant Evaluation Model (a risk-benefit analysis carried out to support the 2010 Clean Air Plan). Work done by ARB under its “Neighborhood Assessment Program,” is then discussed, along with several air board studies completed pursuant to state legislation. Finally, three Bay Area diesel PM risk assessments$^{11}$ are reviewed: two published by ARB as part of its program to reduce pollution from goods movement activities, and one commissioned by the City of San Francisco.

1. BAAQMD’s CARE Program

The main objectives of the air district’s Community Air Risk Evaluation (“CARE”) program are to characterize the cumulative health risks of TACs, identify sensitive populations and highly impacted areas, and develop mitigation measures prioritizing highly impacted areas. BAAQMD estimated TAC emissions from the region’s mobile, point, and area sources during 2000 and 2005. The results showed that a small subset of chemicals was responsible for the bulk of the air pollution hazard.$^{12}$ For carcinogenic effects, five TACs represented 97% of the toxicity-weighted$^{13}$ emissions: diesel PM (86%), 1,3-butadiene (4%), benzene (3%), chromium VI (3%), and formaldehyde (1%). Toxicity-weighted emissions of chronic non-carcinogens were dominated by five TACs: acrolein (61%), formaldehyde (13%), diesel PM (12%), acetaldehyde (4%), and manganese (3%). For acutely toxic emissions, acrolein (97%) and formaldehyde (2%), made up most of the hazard. A large majority of the toxicity-weighted emissions came from mobile sources of pollution.

Figure 2 is adapted from the 2008 CARE technical memorandum$^{13}$ and shows the geographic distribution of the 2005 toxicity-weighted carcinogenic and chronic non-carcinogenic emissions. In both cases, the distribution of hazardous emissions is similar.$^{14}$ One difference, however, is that areas adjacent to major airports stand out as hot spots of non-carcinogenic emissions. This was mainly due to estimated acrolein emissions from aircraft operations. The air district also modeled TAC concentrations and health risk for the region. Figure 3 illustrates the estimated 2005 cancer risk due to five major TACs: Diesel PM, 1,3-butadiene, benzene, acetaldehyde, and formaldehyde.$^{15}$ Higher levels of carcinogenic emissions and cancer risks are generally found in the more urbanized portions of the Bay Area, especially along busy freeways and industrial corridors, and near shipping ports and airports. Emissions and risks were highest near the Port of Oakland, in eastern San Francisco, and along the 880 Freeway in Alameda County.

---

$^{11}$ Diesel PM is the largest contributor to the air-related cancer risk in the Bay Area. Recent BAAQMD and ARB modeling studies indicate that 2005 diesel PM concentrations would produce average risks of about 400 per million over 70 years, with localized hotspots of 1500 per million or more.


$^{13}$ “Toxicity-weighting” refers to adjusting the quantity of an emitted chemical based upon its potency in causing cancer or non-cancer effects.

$^{14}$ Although not depicted in the figure, acute toxicity-weighted emissions showed a similar distribution as the chronic toxicity-weighted emissions, and were dominated by acrolein and formaldehyde emissions.

$^{15}$ This map was created by the author using CARE data provided by BAAQMD (See, ftp://ftp.baaqmd.gov). The data was processed and rendered using ESRI ArcGIS software.
The bulk of the cancer risk in the highly impacted San Francisco grid cells was due to construction diesel emissions (more than 75%) followed by on-road diesel exhaust (approximately 10%). The San Jose area was also broadly impacted by higher risk levels. Smaller zones with relatively high emissions and risks were found near Richmond, the San Francisco Airport, Concord, Antioch, Santa Rosa, Fairfield, and Palo Alto.

The CARE program designated six highly impacted communities, which were defined by considering the estimated cancer risks together with demographic information on potentially sensitive populations (youth, seniors, and people living in poverty). The “CARE communities,” shown in Figure 4, consist of portions of Eastern San Francisco, Western Alameda County, Richmond/San Pablo, San Jose, Redwood City/East Palo Alto, and Concord. The air district estimated that the CARE communities represent approximately 50 percent of population-weighted lifetime cancer risk for sensitive groups consisting of young and older individuals.

Because the CARE analysis estimated emissions on the scale of 1 square kilometer, some smaller scale hot spots are not represented in the results. For instance, any place within 500 feet of a congested roadway could be a hot spot, and places where major construction activities are planned could also present smaller scale air pollution issues. (Figure 4 shows the location of “priority-development areas” documented by the Association of Bay Area Governments, where elevated construction emissions may be expected). There may also be locations where air pollutants other than those prioritized in the CARE studies create elevated risk, e.g., a neighborhood of a few city blocks near one or more small stationary sources could have a cumulative air issue not indicated by the CARE results. It should also be noted that the CARE emissions for several source types were obtained indirectly. For example, county-wide emissions of some area sources were estimated and then portions were allocated to specific grid locations. Therefore, CARE estimates contain uncertainty with regard to both scale and location.

The air district currently plans to refine its CARE program analysis by carrying out air pollution exposure assessments to more accurately identify populations at risk and to determine activities that produce higher risk levels.

16 It should be noted that the CARE 2005 construction diesel emissions may be overestimated. In 2010, ARB revised its statewide construction diesel emission factors using updated information regarding construction activity, vehicle load factors, and other inventory inputs. They concluded that the emissions inventory was significantly lower than previous estimates, in part, due to the economic recession. For example, statewide 2009 diesel emissions from construction vehicles were revised from about 18 tons per day to about 4 tons per day. (See: http://www.arb.ca.gov/msprog/ordiesel/documents/emissions_inventory_presentati_10_09_03.pdf)

Figure 2

Toxicity-Weighted Air Emissions, San Francisco Bay Area, 2005 *

| Carcinogens | Chronic Non-Carcinogens |

* Adapted from the 2008 CARE Tech Memo (supra Footnote 12). Names of the nine BAAQMD counties have been added.
Figure 3

Air Pollution Cancer Risks
San Francisco Bay Area, 2005 *

* Based upon estimated annual average concentrations from BAAQMD CARE 1-kilometer grid air model for 2005, and assuming a 70-year exposure period. Chemicals represented in this map are: Diesel PM, 1,3-butadiene, benzene, acetaldehyde, and formaldehyde.
Figure 4

BAAQMD CARE Priority and ABAG Priority Development Areas

<table>
<thead>
<tr>
<th>CARE Communities *</th>
<th>ABAG Development Areas and CARE Communities **</th>
</tr>
</thead>
</table>

Legend
- Major Airports

Revised Priority Community Boundary
- Concord
- Richmond/San Pablo
- Western Alameda County
- San Jose
- Redwood City/East Palo Alto
- Eastern San Francisco

* Adapted from March 2009 CARE program documentation.
** Map generated with data from BAAQMD CARE and ABAG.
2. BAAQMD PM$_{2.5}$ Studies

The air district has also been studying the sources and dynamics of PM$_{2.5}$ pollution in the Bay Area. In one study the district carried out a chemical mass balance analysis of ambient monitoring data between 1999 and 2001 to identify the major contributors to regional PM$_{2.5}$ concentrations throughout the year and during wintertime episodes of high PM$_{2.5}$.$^{18}$ The major sources of PM$_{2.5}$ were on-road and off-road mobile sources (37% annually and 46% on peak pollution days), wood burning (24% annual and 33% peak), followed by refining, commercial cooking, and other sources. (See Figure 5)

In a second study, BAAQMD developed a model to characterize the formation and transport of PM$_{2.5}$ in the region. PM concentrations were simulated in a 4 kilometer grid during the high-concentration months (December and January) of 2000-01 and 2006-07.$^{19}$ Wood smoke was also modeled for the winter of 2008-09. During episodes, when PM$_{2.5}$ exceeded the federal standard, primary PM$_{2.5}$ levels$^{20}$ were highest near centers of commerce, near industrial facilities along the Carquinez Strait, and in Travis, Santa Rosa and Santa Cruz. Secondary PM$_{2.5}$ was more evenly distributed over the urbanized areas. (See Figure 6) Around San Francisco and San Jose, primary PM$_{2.5}$ emissions could alone cause air concentrations to rise above the standard, whereas in the eastern and northern parts of the Bay Area, a build up of both primary and secondary PM$_{2.5}$ was required to exceed the standard.

Modeling of wood smoke emissions found that this type of PM$_{2.5}$ would be in the range of 10-20 ug/m$^3$ in high wood-burning areas, assuming no regulatory controls. Higher wood smoke concentrations were found in San Jose, northern Contra Costa County, and Santa Rosa (based on one simulated episode). Assuming 100% compliance with the air district’s wood burning restrictions on Spare the Air days$^{21}$ would result in an estimated reduction of wood smoke concentrations of 50-75% depending on the location. The study also looked at the transport of PM$_{2.5}$ from the Central Valley into the Bay Area. During the six highest days of each modeled year, transported PM$_{2.5}$ added 11 to 19 ug/m$^3$ of fine particulate to the air at various Bay Area locations. Transported PM$_{2.5}$ tended to have higher impacts on areas along the Carquinez Strait and Altamont Pass.

3. BAAQMD’s Multi-Pollutant Evaluation Model

The air district has developed a number of “Clean Air Plans” over the years to reduce regional ozone concentrations. For its 2010 Clean Air Plan, BAAQMD took a more cumulative approach by carrying out a multi-pollutant risk-benefit analysis for ozone, PM$_{2.5}$, TACs and greenhouse gases.$^{22}$ The modeled health impacts are summarized in Figure 7, which is reproduced from the multi-pollutant report. The analysis indicated that regional air pollution causes approximately 2,800 premature deaths per year, and that more than 90% of these deaths are due to PM$_{2.5}$ exposure. Fine particulate was also responsible for the bulk of the non-fatal health impacts for these categories.

---


20 Primary PM is PM directly emitted from a source, secondary PM is that which is generated from gaseous pollutants via chemical transformations in the atmosphere.

21 On days when particulate matter levels are anticipated to be high, BAAQMD issues a “Spare the Air Alert” indicating that wood burning is prohibited in the region.

Figure 5

Sources Contributing to PM$_{2.5}$ Concentrations in the Bay Area, 2000

<table>
<thead>
<tr>
<th>Throughout the Year</th>
<th>Peak Pollution Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Burning 24%</td>
<td>Wood Burning 33%</td>
</tr>
<tr>
<td>Other 9%</td>
<td>Other 10%</td>
</tr>
<tr>
<td>Sea Salt 11%</td>
<td>Sea Salt 1%</td>
</tr>
<tr>
<td>Construction &amp; Farming Equipment 12%</td>
<td>Construction &amp; Farming Equipment 12%</td>
</tr>
<tr>
<td>On-road Motor Vehicles 18%</td>
<td>On-road Motor Vehicles 28%</td>
</tr>
<tr>
<td>Commercial Cooking 6%</td>
<td>Commercial Cooking 3%</td>
</tr>
<tr>
<td>Refining 12%</td>
<td>Refining 7%</td>
</tr>
<tr>
<td>Trains, Aircraft, Ships 7%</td>
<td>Trains, Aircraft, Ships 6%</td>
</tr>
</tbody>
</table>

* Graphics reproduced from BAAQMD 2010 Clean Air Plan, pages 2-45 and 2-46 (supra Footnote 17). Note that the “wood burning” category was originally reported in BAAQMD’s modeling report (supra Footnote 18) as “vegetative fires” which includes domestic wood burning plus the minor categories of waste burning, accidental fires, and tobacco smoke.
Figure 6

BAAQMD Modeled Primary and Secondary PM$_{2.5}$ Concentrations for Winter Days Exceeding the Federal Standard *

* Reproduced from BAAQMD modeling study (supra Footnote 19). Concentrations represent the average of simulations on 52 days for which measured Bay Area 24-hr PM$_{2.5}$ level exceeded the federal standard of 35 µg/m$^3$. Note that the modeling domain extends beyond BAAQMD’s nine counties and includes the Central Valley to the east.
A noteworthy conclusion with regard to diesel PM was that the (non-cancer) risk of premature mortality from diesel PM appears to be roughly 10 times higher than the risk it poses as a carcinogen. Regional TAC concentrations (other than diesel PM) and ozone produced relatively small risks compared to PM$_{2.5}$. Five TACs—diesel PM, benzene, 1,3-butadiene, formaldehyde, and acetaldehyde—are responsible for approximately 95% of the estimated cancer risk from air toxics in the Bay Area.

4. ARB’s Neighborhood Assessment and SB 25 Activities

ARB established a “Neighborhood Assessment Program” in 1999 whose goal was to develop guidance on evaluating and addressing cumulative air pollution at the neighborhood scale. The Children’s Environmental Health Protection Act (“SB 25”) was passed in the same year, and required the agency to evaluate air pollution impacts to infants and children, including those with asthma and other vulnerabilities. The air board combined the two objectives into one project and selected a mixed industrial-residential community in San Diego (Barrio Logan) for its initial work.

The study did not include diesel PM. Toxic and criteria air pollutant concentrations at several sites, some chosen specifically to indicate the impact of localized sources, were generally similar to those measured at the larger-scale urban air monitors. However, one industrial facility was identified as an air pollution hot spot affecting several nearby residences.
SB 25 also required an evaluation of the statewide monitoring network that measures average exposure in densely populated areas. ARB chose six representative locations near industry and traffic, including the Fruitvale neighborhood of Oakland and Crockett in Contra Costa County. It found that the statewide monitoring network is generally, but not always, sufficient to characterize outdoor air pollution exposures. One exception identified in the study was a school located about 250 feet away from a major freeway in the Boyle Heights neighborhood of Los Angeles. Its PM10 concentrations were consistently 35% higher than those recorded at the neighborhood monitoring station. To ensure that elevated exposures at near-source locations are properly characterized, the air board recommended the use special purpose monitoring and air quality modeling.23

5. AB 32 Related Activities

California’s Global Warming Solutions Act of 2006 (“AB 32”) required ARB to ensure that activities undertaken pursuant to the law, “do not disproportionately impact low-income communities,” and also to consider the potential cumulative air pollution impacts from the law’s use of cap-and-trade mechanisms. Accordingly, the air board developed a screening method to identify low-income communities impacted by multiple air pollution exposures.24 The communities were identified by ranking California census tracts in terms of air pollution exposures and low-income status. Ozone, PM2.5, and TACs (including diesel PM) were evaluated. Figure 8 shows the results for the Bay Area. There is only partial overlap between ARB’s impacted areas and BAAQMD’s CARE communities (See Figure 4). For example, the ARB analysis did not include the CARE communities of San Jose, East Palo Alto, and Concord. This difference is possibly due to the fact that the statewide ARB analysis used less precise exposure information and considered fewer vulnerability factors than did BAAQMD.

ARB and the California Department of Public Health (CDHP) also completed a joint cumulative impacts study of the AB 32 cap-and-trade regulations. ARB analyzed air impacts25 and CDHP carried out a limited Health Impact Assessment.26 The City of Richmond was one of four representative areas chosen for detailed analysis. The air pollution assessment focused on emissions from industrial and electricity generating facilities subject to the cap-and-trade regulation. It evaluated two scenarios that could produce negative impacts, one where the seven “cap-and-trade” facilities in the Richmond area increased their emissions by 4 percent, and another where a new power plant would be established in the area.

---

Under each scenario, the impact of increased air pollutant emissions was predicted to be negligible or minor. A major shortcoming of the assessment is that ARB assumed the standard air pollution programs alone would effectively limit cumulative air impacts. Since a cumulative risk study is supposed to evaluate combined impacts that could occur in spite of traditional regulatory controls, ARB’s approach begs the question.

In addition, the analysis failed to consider that slowing down the progress of current air pollution control programs should also be seen as a negative cumulative impact, even if air pollution levels consistently decrease over time. These problems are mitigated somewhat by the agency’s commitment to monitor the implementation of the cap-and-trade regulations to ensure that air pollution emissions do not increase as a result.
In the Health Impact Assessment, CDHP evaluated the possible impacts of changes in four major areas: employment, energy costs, community investment, and changes due to offset projects.\textsuperscript{27} Relative to Contra Costa County, Richmond residents were found to be more vulnerable in terms of health status. They had higher rates of asthma, heart disease, stroke, low birth weight, and child obesity. They also had more exposure to environmental stressors such as: a high crime rate, poorer housing, lower air quality and greater proximity to environmental hazards generally. Notwithstanding these increased vulnerabilities and exposures, CDHP concluded that the negative impacts of the cap-and-trade regulations would be minor and readily mitigated.

6. Bay Area Diesel Pollution Studies

This section discusses two Bay Area diesel pollution risk assessments completed by ARB in collaboration with other agencies and one study commissioned by the City of San Francisco. The West Oakland diesel risk assessment was prepared by the air board with input from BAAQMD, the Oakland Port Authority, and Union Pacific Railroad.\textsuperscript{28} It estimated diesel PM emissions and concentrations from operations at the Port of Oakland, the Union Pacific rail yard, and various other West Oakland sources.\textsuperscript{29} The assessment found that West Oakland is exposed to diesel PM concentrations about three times higher than the average for the Bay Area. The average West Oakland diesel PM cancer risk was about 1,200-per-million, assuming 70 years of exposure to 2005 levels of diesel PM. The largest contribution to this risk was from on-road diesel truck traffic. Although West Oakland had the highest levels of diesel PM, the diesel plume extended over 550,000 acres, impacting more than 3 million people and producing a population-weighted cancer risk of about 30-per-million. Ocean-going vessels were the largest contributor (85 percent) to this urban-scale risk. Figure 9, taken from the report, shows the cancer risk contours for West Oakland. While average neighborhood risk appears to be about 1,200, there are hot spots at 1,500-per-million or higher. In addition, diesel PM from the Port could result in “18 premature deaths per year, 8 hospital admissions for respiratory and cardiovascular problems, about 290 cases of asthma-related and other lower respiratory symptoms, and 15,000 minor restricted activity days.”\textsuperscript{30}

BAAQMD sponsored a supplemental West Oakland air sampling program to validate ARB’s modeling results and to better characterize local concentrations of diesel PM and other air pollutants.\textsuperscript{31} Mobile source pollution was found to be elevated within about 300 meters of West Oakland’s major traffic corridors. On-road diesel PM concentrations along the I-880 were more than 5 times higher than the community average. The study also showed that measured 2009-2010 diesel PM concentrations in West Oakland neighborhoods were consistently lower than the ARB modeled 2005 concentrations by a factor of about two.

\textsuperscript{27} Under the cap-and-trade rule, offsets are greenhouse gas reductions that are obtained by activities not covered by the regulation.


\textsuperscript{29} The diesel PM sources included in the study were: boats and ships, cargo-handling equipment, trucks, locomotives, diesel refrigeration units, large construction projects, stationary point sources, and truck-based businesses.

\textsuperscript{30} Id. at page 36.

The second ARB risk assessment looked at diesel PM from the BNSF rail yard in Richmond.\textsuperscript{32} Emissions during 2005 were estimated for locomotives, cargo handling, locomotive servicing, track maintenance, and other support operations. Mobile and stationary sources within one mile of the rail yard were also evaluated. The rail yard emitted an estimated 4.6 tons per year of diesel PM and 19.8 tons per year of diesel PM were emitted from sources in the surrounding area. About 70 percent of rail yard emissions came from locomotives, and mobile sources made up about 60 percent of emissions in the surrounding area. The Chevron refinery, which is located within the 1 mile radius, was estimated to have emitted about 8 tons-per-year of diesel PM in 2005. Risks above 10-per-million were generated by the rail yard and extended nearly a mile into residential areas. Risks from vicinity-source emissions were generally higher than those from the rail yard. For example, vicinity-source risks of 25 to 250-per-million were found within one mile of the rail yard boundary.

\textsuperscript{32} ARB, Stationary Source Division, “Health Risk Assessment for the BNSF Railway Richmond Railyard,” November 20, 2007. (http://www.arb.ca.gov/railyard/hra/bnsf_richmond_hra.pdf) This study was completed as part of a railroad pollution reduction agreement between ARB and the Southern Pacific and BNSF railroad companies.
This study did not include several nearby sources of diesel PM, for example, Chevron’s Richmond Long Wharf Marine Terminal and emissions from the Port of Richmond.

Finally, the San Francisco Department of the Environment published a report estimating year 2007 emissions and health risks from diesel PM sources in Bayview Hunters Point area of San Francisco. The study did not include diesel pollution from the nearby Port of San Francisco operations. Trucks and busses, railroad locomotives, construction activities, and stationary diesel engines were estimated to emit a total of 7.8 tons of diesel PM. About 70 percent of diesel PM emissions came from off-road mobile sources used in construction projects and an additional 23 percent from trucks and buses. The remaining 7 percent came from stationary diesel backup generators and railroad locomotives.

The modeled cancer risks, based on 2007 emissions projected 70 years into the future, were relatively uniform at 100 to 200-per-million across most of Bayview Hunters Point. However, a few hot spots were found near places with numerous diesel backup generators. One hot spot with up to 900-per-million risk was identified near the City Central Shops and Southeast Water Treatment plant (the locations of 45 diesel backup generators). This study shows the impact of dispersed and concentrated sources of air pollution, and indicates the need to consider both average neighborhood exposure as well as near-source exposure.

III. Policies for Reducing Cumulative Air Pollution

The studies discussed in this review have contributed to a better understanding of cumulative air pollution exposure and hot spots in the San Francisco Bay Area. Some conclusions that policy-makers have drawn from this research are: (i) that on-road and off-road mobile sources are a major source of regional air pollution, (ii) that PM$_{2.5}$ pollution, including diesel PM, is a major component of cumulative air risk and primary PM is an important aspect of this pollution, and (iii) that air pollution hot spots exist throughout the region, typically associated with congested traffic zones, goods movement activities, development projects, and areas of concentrated industrial activity (and that there are vulnerable communities living near these areas).

These issues are being dealt with through a combination of new regulations and voluntary/incentive programs. In particular, ARB has a variety of statewide regulatory programs to reduce diesel and mobile source pollution, such as its Diesel Risk Reduction Plan, its Emission Reduction Plan for Ports and Goods Movement, and its other mobile source activities. Federal actions have also played a part. For example, the recent strengthening of the national ambient PM$_{2.5}$ standard requires an evaluation to ensure that certain federally-funded transportation and development projects do not create or exacerbate PM$_{2.5}$ hot spots. BAAQMD’s 2010 Clean Air Plan includes measures to strengthen several of its PM regulations. The plan also contains a variety of mostly non-regulatory measures to reduce the air impacts of land-use decisions and decrease transportation pollution.


35 For example, the air district will update its general regulation on particulate matter emissions, will promulgate a new rule for metal-melting facilities, and is considering further controls on wood-smoke emissions. The plan’s goals include a 10 percent reduction in population PM$_{2.5}$ exposure by 2015.
These include grant and incentive programs, partnering with other agencies to create pollution reduction plans, educational activities, and joint enforcement of ARB regulations.  

In 2010, the air district also revised its California Environmental Quality Act ("CEQA") air quality guidelines, providing updated significance thresholds and new tools to characterize cumulative air impacts. The guidelines cover new pollution-emitting projects and projects that place people close to air pollution sources (e.g., a housing complex built next to a freeway). For cumulative impacts, BAAQMD recommends evaluating TAC and PM\textsubscript{2.5} emissions from mobile and stationary sources, generally within 1000 feet of a project site. The cumulative impact significance criteria include: a PM\textsubscript{2.5} concentration of 0.8 \text{ug/m}^3, a hazard index of 10, and a 100-per-million cancer risk. 

Air quality agencies have also produced a variety of guidelines to more directly address risks to vulnerable communities. An early contribution was made by ARB’s Community Health Program, which published 2005 air quality guidelines to assist local governments in permitting the construction of new residences, schools, and other land uses that involve environmentally vulnerable populations. Buffer zones are proposed to avoid development in areas of high air pollution. (See Table 2) 

More recently, BAAQMD published guidelines that propose Community Risk Reduction Plans ("CRRPs") as a way to reduce air risk in disproportionately impacted areas with vulnerable communities. A CRRP would be a multi-year plan created by land-use agencies to: (i) reduce cumulative TAC and PM\textsubscript{2.5} exposures, (ii) evaluate development proposals more consistently, and (iii) streamline the CEQA review process. Cumulative air impacts within a designated planning area (e.g., a city subsection) would be reduced over time using methods such as voluntary and incentive programs, negotiations with businesses, and regulations. The decision to adopt a CRRP is voluntary, but land-use agencies have an incentive to develop a BAAQMD-approved plan to take advantage of CEQA streamlining. New projects in areas covered by a CRRP and consistent with the plan would not need to be evaluated against the CEQA air quality significance thresholds. The cities of San Francisco and San Jose are writing CRRPs.

---

36 For instance, the air district provides grants to replace old engines and vehicles with newer cleaner models, and it collaborated with the Port of Oakland, community groups, and maritime industry representatives to create a diesel reduction plan for the Port.


38 These values have been criticized by health advocates as insufficiently protective. In particular, allowing hazard indices to rise up to 10 without further analysis is problematic given the principles on which the hazard index method is based.


40 Along these lines, the City of San Francisco passed a regulation to mitigate traffic-related PM\textsubscript{2.5} health impacts arising from the placement of new residential buildings in high traffic areas. See, Bhatia R. and Rivard T., “Assessment and Mitigation of Air Pollutant Health Effects from Intra-urban Roadways: Guidance for Land Use Planning and Environmental Review, Department of Public Health, City and County of San Francisco,” May 6, 2008. (http://www.sfdph.org/dph/eh/Air/MitRoadway111907.pdf)

### Table 2

**ARB Land Use Guidelines: Recommended Buffer Zones***

<table>
<thead>
<tr>
<th>Source Category</th>
<th>Source Details</th>
<th>Buffer Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeways and High-Traffic Roads</td>
<td>Urban, 100,000 vehicles/day or Rural, 50,000 vehicles/day</td>
<td>500 feet</td>
</tr>
<tr>
<td>Distribution Centers</td>
<td>&gt; 100 trucks per day, or &gt; 40 trucks per day with transport refrigeration units (TRUs), or &gt;300 hours per week of TRU use</td>
<td>1,000 feet (and avoid land uses near entry and exit points)</td>
</tr>
<tr>
<td>Rail Yards</td>
<td>Major service and maintenance yard</td>
<td>1,000 feet (plus siting limitations and mitigation approaches within 1 mile)</td>
</tr>
<tr>
<td>Ports</td>
<td></td>
<td>Immediate downwind areas</td>
</tr>
<tr>
<td>Refineries</td>
<td></td>
<td>Immediate downwind areas</td>
</tr>
<tr>
<td>Chrome Platers</td>
<td></td>
<td>1,000 feet</td>
</tr>
<tr>
<td>Dry Cleaners Using Perchloroethylene</td>
<td>Any dry cleaner</td>
<td>300 feet</td>
</tr>
<tr>
<td></td>
<td>Two or more machines</td>
<td>500 feet</td>
</tr>
<tr>
<td></td>
<td>Three or more machines</td>
<td>Consult with the local air district</td>
</tr>
<tr>
<td></td>
<td>General</td>
<td>Do not site sensitive uses in the same building with perchloroethylene operations</td>
</tr>
<tr>
<td>Gasoline Dispensing Facilities</td>
<td>Typical gas station</td>
<td>50 feet</td>
</tr>
<tr>
<td></td>
<td>3.6 million gallons per year or more dispensed</td>
<td>300 feet</td>
</tr>
</tbody>
</table>

* Adapted from ARB guidelines (supra Footnote 39).

### IV. Improving Cumulative Air Risk Reduction Programs

At the present time, a wide variety of measures are being proposed and implemented by regulatory agencies to address the main components of the cumulative air risk problem. However, there are still some issues that remain to be acknowledged and resolved to ensure adequate health protection in pollution hot spots and to decrease environmental inequities for all communities in the Bay Area. This section will discuss a few of these and provide recommendations.

- **Better measures of community vulnerability should be incorporated into cumulative risk evaluation methods.** Standard risk assessment methodology considers differential sensitivity due to certain intrinsic factors, such as age or biological variation, but is lacking when it comes to accounting for extrinsic factors such as psychosocial stress. Sensitivity arising from intrinsic and extrinsic factors has been referred to, respectively, as susceptibility and vulnerability.42 Some of the cumulative risk studies reviewed above used income level or poverty status as a surrogate for community vulnerability (e.g., the CARE and AB 32 communities were defined this way). While this is a good first step, using poverty status alone may miss some vulnerable neighborhoods. A more detailed characterization of vulnerability would give agencies a better picture of where pollution reduction

---

42 This terminology has been proposed by Morello-Frosch, R. et al., (supra Footnote 1).
efforts should be focused, and would also be helpful in determining criteria to protect public health with an adequate margin of safety. Two available methodologies that allow a finer assessment of community vulnerability are: Cal/EPA’s cumulative impacts framework methodology and the environmental justice screening method developed by Pastor, et al. in support of ARB’s AB 32 cumulative impact evaluations.43

- **BAAQMD** should adopt a broad definition of cumulative risk. As stated in its CEQA guidelines, the air district considers cumulative risk as arising from exposure to TAC and PM$_{2.5}$ emissions from mobile, stationary, and area sources in an area. The air district’s treatment of other important aspects of cumulative risk has not yet been clearly stated. The CARE communities were defined by considering air toxics exposure together with age and poverty status. In conjunction with improving its cumulative risk methodology, as recommended above, the air district should adopt a more comprehensive definition of cumulative risk, such as the one provided in Cal/EPA’s cumulative impacts framework document. The Cal/EPA definition incorporates broader concepts of community exposure and vulnerability.

- **Increased emphasis** should be placed on reducing all forms of PM pollution. Reducing PM$_{2.5}$ concentrations is an important health objective for the Bay Area given the level of health impact this pollutant poses and that the area is out of attainment with the federal standard. However, attaining the federal PM$_{2.5}$ standard should not be seen as the only PM-related goal that is worthy of regulatory attention. The Bay Area is also out of attainment with the more stringent California PM standards (both PM$_{2.5}$ and PM$_{10}$) and regulatory measures should be adopted to also comply with these standards. The air district should not ignore the potential harm to communities from coarse particle exposure (coarse particles are those in the range of 2.5 to 10 microns). Although recent research has indicated that finer particles tend to have greater toxic potency, coarse particles, specifically those generated in urban environments, are still considered to be toxic by the scientific community and state and federal regulators.

- **There is a need** to ensure that both larger and smaller communities are being adequately protected from cumulative air risk. Air pollution hot spots can exist at a variety of geographic scales, from city sub-sections to areas the size of a few city blocks. In addition to BAAQMD’s six relatively large CARE priority zones, numerous small-scale hot spots are likely to be present throughout the Bay Area. These smaller hot spots could be produced, for example, by loosely regulated old or small pollution sources of PM, or by commercial and industrial facilities that attract diesel and other traffic to a neighborhood. Other potential hot spots include places near airports and air fields (CARE non-cancer data indicated a potential problem with regard to acrolein, a pollutant that is present in aircraft emissions). Studies have also indicated that narrow strips along the major freeways have relatively high cancer risks and PM health impacts. Many of these areas are outside of the air district’s CARE communities. As a matter of environmental justice, it is important to identify and reduce risks in smaller hot spots as well as the larger ones. In this context, the air district could improve its cumulative air pollution program by engaging in more local-scale monitoring, and by making more use of its recently developed mobile sampling laboratory to investigate potential micro-scale air pollution issues raised by community groups (or otherwise identified by staff). A Bay Area inventory of indirect sources and one for grandfathered point sources would also be useful.

---

43 These studies are cited in Footnotes 7 and 24.

44 The term grandfathered source refers to a pollution-emitting process that has been exempted from a rule because it existed and was permitted prior to adoption of the rule.
Additional regulatory action is needed to reduce cumulative risk. The main weakness in current cumulative risk initiatives is that they are mostly voluntary and do not include mandates to reduce pollution. Ensuring the timely reduction of cumulative air risks will require state and local agencies to adopt additional regulatory measures aimed at already existing sources of pollution. This may be difficult in cases where agencies lack statutory authority or where that authority is unclear. It is particularly a problem in regard to pollution issues that arise from inappropriate land use planning since city governments control these types of decisions. In some cases, community advocates may need to pursue new legislation. Nonetheless, agencies like BAAQMD and ARB have some authority to develop regulatory measures to further reduce risks in cumulative hot spot areas. At the state level, Cal/EPA should prioritize developing explicit cumulative impact guidelines for its boards, offices, and departments. ARB could promulgate cumulative risk regulations. Even BAAQMD could develop a cumulative risk regulation to ensure that cumulative risk gaps are addressed.

Air quality agencies should take additional steps to harmonize the currently separate CAP and TAC programs. For example, with regard to BAAQMD’s permit process, a risk assessment carried out for an industrial facility emitting TACs should include the potential additive impacts of any CAPs that it emits, and ambient background levels of all pollutants should be considered in setting health-protective restrictions on permitted emissions. For facilities that emit CAPs, primary CAP emissions should be treated in the same manner as TACs. Thus, a small facility emitting PM or sulfur dioxide would be evaluated via a risk assessment in the same fashion as for facilities that emit TACs. Current regulations for small CAP-emitting facilities do not require air modeling or health risk evaluations. This would likely be most important for point sources of primary PM since PM has been identified as a predominant source of air risk in the region.\(^{45}\)

\(^{45}\) The author used the ISC-Prime air dispersion model to evaluate the localized air impact of smaller PM sources. The results showed that currently permitted PM emissions from some point sources could significantly degrade local air quality and cause exceedances of the California air quality standards. For example, a point source emitting 10 tons-per-year of PM from the roof of a typical industrial building with a low stack could produce a 24-hour concentration greater than 25 ug/m\(^3\) within 3 city blocks of the building.