A Breath of Fresh Air

How environmentalists, health experts, and poverty advocates are forging new coalitions to tackle an urban asthma epidemic

BY GEOFFREY LOMAX, ERIC ROBERTS, AND PAUL ENGLISH

THE CROWNING ACHIEVEMENT IN urban health came in the late-19th and early-20th centuries, when a series of broad changes transformed the social and material environment for millions of inner-city Americans. Important policies aimed at improving children's health, working conditions, housing, and public sanitation translated into dramatic improvements in the health of the average American. And they happened, largely, because Americans in the Progressive Era had come to recognize that "health" is inextricably linked to the much broader social, economic, and environmental conditions in which people live.

In more recent decades, however, this enlightened ideal regrettably gave way to a narrower, segmented thinking about health care in which the health of people was considered separately from the conditions of their environment, housing, and workplace. Epidemiologists—scientists who study causes of disease and how illness is distributed in populations—increasingly focused on individual "risk factors," such as smoking and diet, while neglecting the social influences that affect both health and behavior. As medicine became consolidated as its own sovereign profession, doctors also concentrated on changing individual risk behaviors, often leaving political and industry influences on health blameless. This shift still characterizes the way most experts think about the epidemic of urban asthma, and it is evident in the political response to the disease.

Odd as it may seem, the asthma scourge creates an opportunity for a promising sort of coalition politics, one in which traditional environmentalists concerned about dirty cities join advocates in the low-income housing community, health-care officials, and others to promote new thinking and real results. Just such an approach is under way today in California, where our State Department of Health Services has partnered with neighborhood advocacy organizations, local health agencies, and environmental groups to develop a system that provides a unique view of patterns of urban asthma. The results are helping policymakers and community advocates target the intersection of social deprivation, environmental injustice, and adverse health to find solutions to our asthma epidemic.

Poor and minority children suffer a disproportionate burden of asthma, at least in part because of the environmental conditions where they live. In homes, schools, and workplaces, mold, dust mites, and even cockroaches trigger acute attacks and may promote the development of the disease itself. Also implicated are broader environmental hazards—from elevated ozone to diesel fumes and other airborne pollutants—which are also more concentrated in poor communities. In addition, poor people and children of color are less likely to get preventive care for asthma because they lack decent health insurance. This means they are more susceptible to ongoing symptoms as well as more serious attacks that lead to emergency-room treatment and hospital stays.

The preventive regimen for asthmatics is now well established. Nearly all children prone to asthma can remain largely attack-free through monitoring and relatively simple medications. But children of the poor, in addition to living in hazardous environments, are less likely to have access to this preventive approach.

Typically, "solutions" to the epidemic have been piecemeal. Environmental groups focus on air-pollution issues while housing experts lobby for cleaner, safer homes. Health-care and labor-rights advocates seek improved access to care, especially for children, without a coordinated effort to address the root causes. These piecemeal efforts—cleaning up outdoor air without corresponding improvements in homes, schools, and workplaces, for example—can result in high costs without measurable health benefits. And they obscure broader thinking about the relationship among issues affecting class, race, income, and public health.

With an eye toward better solutions to urban-health crises like asthma, the national Institute of Medicine and the Pew Foundation's Environmental Health Commission have pushed for better coordination of research on how environmental conditions affect human health. In 2002, Congress responded, funding a new, national Environmental Public Health Tracking Program. In California, this initiative is helping our team of researchers evaluate patterns of asthma in Alameda County, which is part of the San Francisco Bay area. Along with asthma, rates of unemployment, poverty, overcrowding, and homeownership are merged with locations of schools, roadways, and toxic sites, and are displayed in a geographic information system being developed for the Internet. Maps that can be printed from this system provide strong evidence to push for changes in land-use decisions, housing developments, and even diesel-truck routes, which can result in a multipronged assault on causes of asthma.

FOR ALL THE ATTENTION GIVEN TO the problem of asthma over time, it is maddeningly difficult to answer a simple question: How much asthma exists? Diagnosing it can be highly subjective, and clinicians often disagree even about a single patient's condition. There is no single test that can be used to establish the diagnosis, and no "asthma registries" indicating how many people in a community have the disease. To further complicate matters, a large percentage of the affected population suffers from asthma symptoms but never encounter the health-care system. In the absence of complete information, public-health agencies have tried to make the best of limited data—relying on reported hospitalizations or emergency-room visits for asthma attacks, for instance. But these indicators represent only the tip of the iceberg for asthma treatment; doctors' office visits and obtaining medication are far more common and preferable events, but much harder to track.

While imprecise, these indicators are suggestive of overall trends. For example, emergency-room visits due to asthma have increased in recent years. Yet we know that hospitalization and emergency-room figures tend to paint a distorted picture of the overall problem, one skewed heavily toward poor patients who are more likely to depend on the emergency room for their basic health-care needs. Consider the conclusions of a recent study in the *Annals of Allergy, Asthma & Immunology*, which found that African American asthmatics in Chicago are six times more likely than whites to go to the emergency room and 12 times more likely to be hospitalized. If one were to map these results, the asthma problem would appear to be six to 12 times worse in inner-city neighborhoods with a high proportion of low-income families.

To gain a more complete understanding of the challenge, our department created a partnership with the largest private health-care provider in the county, Kaiser Permanente of Northern California, and the largest public provider of care for the poor, Medi-Cal (our Medicaid system). Both programs already maintained extensive databases of patients and a broad spectrum of asthma "events"—emergency-room visits, but also physician visits, the use of asthma medication, and more. Using these data, we mapped our findings by neighborhood and came up with some vivid pictures. Several areas—particularly those with many low-income families and people of color—showed alarming spikes in emergency-room visits for asthma cases, especially among children. Often these neighborhoods were dealing with poor housing and acute environmental issues, such as proximity to freeways, major shipping ports, or industrial facilities.

But more affluent neighborhoods with quality housing at a distance from freeways and industry often showed elevated rates in other asthma indicators, such as purchases of prescription asthma drugs. These data tell us that the asthma epidemic doesn't afflict poor communities alone; it is distributed widely throughout the county, although its appearance may vary by community social status. Surely there is a quality-of-care component, with poorly managed asthma being concentrated in less-affluent communities. This picture did not fit the agenda of any single "interest group"; environmental advocates could certainly find evidence for framing asthma as an environmental issue, but groups working for health-care reform, fair housing, or other social-justice issues could all make similar claims.

The Air She Breathes: Where public health meets the environment

AP/WIDE WORLD PHOTO

As our work in Alameda County continues, it is teaching us important lessons about our own institutional biases. A case in point: As environmental-health specialists, we were initially concerned with pollution arising from traffic and industry and its likely link to asthma. Even before the asthma data became available, however, many of our community-based partners insisted that this concept of "environment" was too narrow. It is noteworthy that many of these community advisers came from grass-roots organizations and brought an appreciation of the social, economic, and environmental issues related to asthma. They recognized that pollution can threaten human health, but also that health is a function of many less tangible factors: patterns of economic development, crime, and access to health clinics, grocery stores, and even green space.

The group agreed: While air pollution is important, it is only the beginning of a description of "community environment" as it relates to health and well being. Neither health nor pollution could be separated from fundamental social-justice concerns such as housing rights, school quality, jobs, or the distribution of resources in communities. The asthma picture merely reiterated this fact and provided an opportunity around which actors with diverse interests could crystallize.

The final chapters of this story have yet to be written. Locally, the California program—following recommendations from the Alameda County project advisory team—has been collaborating with individuals and groups committed to environmental justice, community economic development, and access to quality health care, schools, and housing. The California story, which is applicable to urban health in general, remains a demonstration of how "narrow" environmental health issues refused to remain in their neat little boxes. Instead, they not only cut across issues of class, race, income distribution, and public health but provided organizing opportunities in which the connections among all of these issues become visible. By making these connections, we can go back to the future and forge new collations for urban health. TAP

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California's New Environmental Health Tracking Programs

Paul English, PhD and John Balmes, MD

In the wake of 9/11, renewed resources and attention have been given to the nation's public health infrastructure, especially in the areas of surveillance of acute infectious illnesses and monitoring the environment for suspicious peaks of chemical contamination. California should rightly devote resources for preparation for a chemical or biological terrorist attack. However, at the same time, we should not neglect the financial and human toll of chronic disease. Chronic diseases are the cause of approximately 75 percent of deaths in California. Unlike with infectious diseases, clinicians are not mandated to report many chronic diseases and therefore public health agencies are unable to track trends over time to determine if they are changing in specific populations or geographic areas.

Environmental exposures contribute to a significant proportion of many chronic diseases (e.g., 30 percent of childhood asthma exacerbations and 10 percent of childhood neurobehavioral disorders are attributed to environmental exposures).(1) Analyses of twin cohorts indicate that genetic factors only explain a minor part of the etiology of cancer and that the environment plays a major role.(2) The toll of environmentally-related chronic disease in California is significant. For just nine of these preventable diseases (such as childhood asthma, lead poisoning and childhood cancer) in which cost estimates are available, total costs for Californians are an estimated $10 billion per year.(3) The estimated total costs in California for work-related deaths in 1992 were $20.7 billion.4 Many workers die each year in California from preventable diseases caused by chemical exposuress.(4)

For some diseases with clear environmental links, incidence is rising; for example, the prevalence of adult asthma in California increased 76 percent between 1984 and 2002.(5) Other diseases with suspected environmental links are also increasing, such as autism (with observed diagnosed cases increasing 80 percent from 1989 to 1992 in California)(6) and testicular cancer (the most common cancer among young men in California, increasing 51 percent nationwide from 1973 to 1995).(7)

In response to the rising burden of disease caused or exacerbated by environmental factors, the California Legislature passed and the Governor signed Senate Bill 702 in 2001. This law made California the first state in the nation to begin planning an environmental public health surveillance system. The goal of such a system is "to establish ongoing surveillance of the environmental exposures and diseases affecting Californians, with a focus on prevalence and determinants of chronic diseases."(8) The University of California, the California Department of Health Services, and the California EPA (CalEPA) partnered to form a steering committee and a panel of experts as mandated by SB 702 to develop recommendations on how such a system would be developed (see final report at www.catracking.com). One of the main recommendations is that the state establish an interagency DHS/CalEPA Office of Environmental Health Tracking to promote collaboration and integrate environmental health data.

In October 2002, the federal Centers for Disease Control and Prevention provided funding for 17 states, 3 local health departments, and three schools of public health to begin development of a National Environmental Public Health Tracking Network. The California Department of Health Services (CDHS) and the University of California, Berkeley were among the recipients of these awards. The CDHS program has the following goals:

- To increase value to existing disease registries by activities such as adding environmental exposure data;
- To establish chemical hazard tracking for the state;
- To develop state biological monitoring capabilities;
- To develop surveys that expand environmental monitoring/modeling to assess exposures;
- To develop innovative ways of interpreting and disseminating environmental health data while preserving data privacy and confidentiality; and
- To promote risk communication and health education to address disease cluster and environmental health concerns among the public.

The CDHS program is working to accomplish these goals by (1) convening a planning consortium of state agencies, nongovernmental organizations, environmental groups and community-based organizations to help plan, implement and evaluate a tracking network; (2) identifying and prioritizing state and local needs for tracking; (3) collaborating with the UC Tracking Center to develop training programs; (4) developing technical plans for an electronic standards-based tracking network; (5) developing an outreach and education strategy for communicating information; and (6) conducting two pilot demonstration projects. The demonstration projects include (1) examining the distribution of asthma and adverse reproductive outcomes in Alameda County and their relation to traffic-exhaust exposures; and (2) examining the distribution of airborne toxins and pesticides in relation to childhood blood levels of lead and other outcomes of pregnancy and childhood neurodevelopment. The primary mission of the UC Berkeley Center for Environmental Public Health Tracking is to help develop the National Environmental Health Tracking Network and to support funded states in this effort. The center is also developing special projects, including:

- Evaluating the use of the California Health Interview Survey to link data on air pollution and asthma with data on sociodemographic factors, asthma management, access to care, and risk behaviors. The usefulness of this model system for tracking other chronic diseases, such as cardiovascular, cancer, and developmental disorders in relation to environmental exposures, will also be evaluated.

- Assisting health departments with asthma tracking by a) assessing the utility of various methods of measuring exposure to traffic-related pollutants and their impact on asthma in children using data from the Fresno Asthmatic Children's Study, and b) developing reliable methods for asthma screening in schools.
- Using biomarker data, emissions data, and exposure media measurements in mathematical models to determine limits of uncertainty regarding linkages between biological monitoring results and both exposures and health effects.
- Identifying the most relevant contaminants to measure, both in the environment and in humans, and the diseases that are at least partly caused or exacerbated by environmental factors. This project is also assessing the availability of data and developing informative methods to report the data to assess trends over time, differences between geographic areas, and differences by race/ethnicity and socioeconomic status.

Both the CDHS and the UC center are committed to working with community groups to provide access to needed environmental and health data while preserving data confidentiality and privacy rights of individuals. New developments in information technologies and geographic information systems are allowing us to present these data in a format and scale needed for communities while protecting data privacy.(9)

CalEPA has made a commitment to environmental justice principles and is working on making air contaminant data, for example, more available to communities with the introduction of its Community Health Air Pollution Information System (CHAPIS), a web-based mapping site, that will provide interactive maps of air pollution emission sources. Clinicians can also play an important role in developing environmental health surveillance. The use of Doctor's First Reports of Illness (DFRs) forms the backbone of occupational surveillance for asthma and pesticide illness. However, more resources are needed to improve insurer submissions of DFRs and to provide outreach and education to clinicians about work-related illness to improve the timely submission of these reports. Electronic reporting of DFRs would greatly enhance existing occupational disease surveillance and prevention efforts.

California has traditionally led the nation in environmental health protection for its residents. Last year, it was the first state to ban PBDEs (polybrominated diphenyl ethers), which are toxic flame retardant contaminants that have been found to be accumulating in human breast milk and wildlife tissues.(10) Women tested in California have levels that are ten to 100 times greater than human tissue levels in Europe.(11) California is also requiring its Air Resources Board to develop and adopt regulations that achieve the maximum feasible reduction of greenhouse gases emitted by vehicles and trucks by 2005.

Although these developments are encouraging, the state must actively remain on the cutting edge of environmental health by using the tools of biomonitoring and chemical hazard tracking to identify and reduce harmful environmental exposures for its residents. For example, data from the 1960s show that levels of DDT metabolites in serum were higher in women of childbearing age who were born in California or the Southeast compared to the rest of the country.(12) Currently, we have no representative California-specific data on pesticide metabolites to corroborate these findings. Limited data regarding the use and distribution of chemical hazards in California represents a major gap for environmental health surveillance. While thousands of chemicals are produced or imported into the U.S. each year, the EPA has estimated that complete basic toxicity information is publicly available for only 7 percent of the high-volume chemicals manufactured in this country.(13) The lack of these data especially presents a hazard for California workers who may be exposed to these compounds. Even if the state had laboratory capacity for detecting all of these compounds in human tissues, no laboratory methods have been developed for many of these chemicals.

As resources for the state health and environmental departments and the UC system are declining, California needs to partner with clinicians, private industry, and community and environmental groups to protect the public from environmental health threats. Ultimately, though, the public sector has the responsibility to safeguard the public interest and health of its residents. We are confident that the initial work being accomplished by California's Environmental Health Tracking Programs will be the beginning of a collaborative partnership that will bring together all stakeholder interests to improve the environmental health of Californians. We invite you to join us in helping us plan this exciting and important initiative.

This information was previously published and was isupported by Grant/Cooperative Agreement Numbers U50/CCU922449 and U50/CCU922409 from the Centers for Disease Control and Prevention (CDC).

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Fall 2005

Environmental Health Tracking:

Partnering with Communities to Prevent Disease

Holly Brown-Williams and Geoffrey Lomax

Unanswered Questions

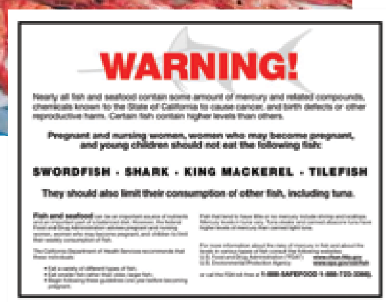
Leslie Guttierez lives in rural Kern County, California. She had eagerly awaited the births of her twin daughters, already named Marie and Maria. Suddenly, she was mourning their unexplained deaths soon after their premature births.

According to the *San Francisco Chronicle* reporters who featured her story in an investigative series on toxic contamination and infant mortality, Leslie was healthy. She did not smoke, drink, or take drugs. And she received regular medical care during her pregnancy. So, why did Leslie's babies die?

Kern County is heavily agricultural. With its high levels of biological and chemical waste, it ranks as one of the nation's most polluted counties. The *Chronicle* analyzed infant mortality information between 1992 and 2001 and found that the death rate among Hispanics was twice as high in Leslie's zip code than in California as a whole.

Conflicting Messages

In San Francisco, Matthew Davis was by all measures a healthy child. However, as reported by the *San Francisco Chronicle* and *The Wall Street Journal*, Matthew's school performance began to drop in the 5th grade. This sudden decline followed the appearance of problems that were later diagnosed by a neurologist as symptoms of mercury poisoning. The suspected cause was high consumption of canned tuna. Tuna was Matthew's favorite food, and it was considered a healthy choice by his parents.



Under Proposition 65 in California, businesses are being required to post warnings about the dangers of mercury contamination in some fish.

Fortunately, Matthew's symptoms have ceased since he stopped eating canned tuna. However, public policies have not changed, and consumers are not alerted to the risks of exceeding the U.S. Food and Drug Administration's recommended consumption of canned tuna (not more than one 6-ounce serving—one average meal—of canned albacore tuna or two 6-ounce servings of canned light tuna per week).

Stories like these are common in newspapers across the country. There is growing concern about the link between environmental pollutants and a wide range of illnesses, from respiratory, neurological, and immune disorders to cancer. These concerns led to the creation of the Pew Environmental Health Commission, which in September 2000 issued a report calling for the creation of a nationwide environmental health-tracking network.

"Disease tracking is the most basic and necessary tool for disease prevention and control. The fact that America, the most technologically advanced country in the world, does not have such a national system in place in the 21st century is a tragedy. This is the key to saving millions of lives."

Shelley Hearne
Trust for America's Health

A National Call to Action

In 2001, in response to the Pew Commission report and other calls to action, Congress appropriated funds to the Centers for Disease Control and Prevention (CDC) to "improve the health of communities" by developing a system to assess data on environmental hazards and exposures in relation to data on health conditions. In 2002, the CDC awarded grants to 17 states, 3 local health departments, and 3 schools of public health to begin to develop a national environmental public health-tracking network. The CDC noted, "The environment plays an important role in human development and health. Researchers have linked exposures to some environmental hazards with specific diseases; for example, exposure to asbestos and lung cancer. Other associations between environmental exposures and health effects are suspected but need further research; for example, the link between bladder cancer and exposure to disinfectant by-products."

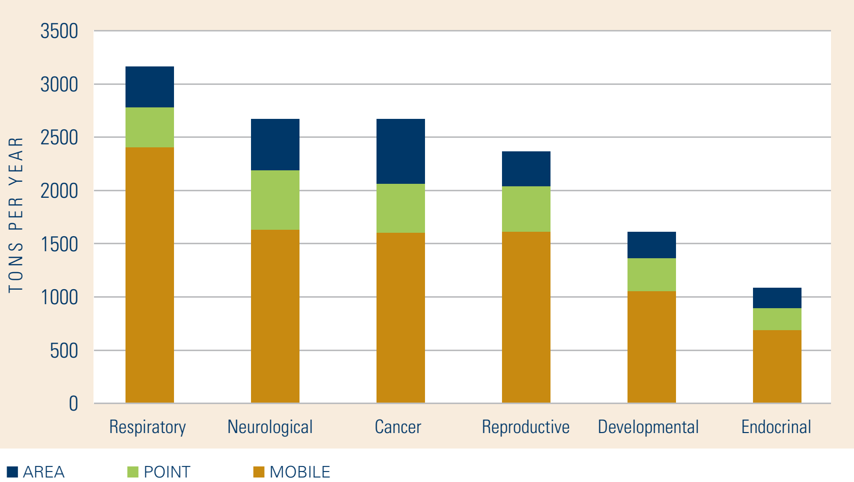
Through the CDC grants in 2002, California received funds to establish a center of excellence in Environmental Public Health Tracking at the University of California, Berkeley. The state also received funds to establish the California Environmental Health Tracking Program, under the joint administration of the Department of Health Services and the California Environmental Protection Agency.

Cause for Concern

The two stories cited above are just a few of many recent warning signs. Approximately 7 out of every 10 deaths in the United States are caused by chronic diseases, and there is growing scientific evidence that environmental factors (e.g., pesticides and toxic air pollutants) are strongly linked to many chronic diseases, including asthma, birth defects, and cancers. For example, benzene exposure is known to cause cancer in humans. Benzene is commonly found in the air, and the exposure allowable by current law is <1ppm. A recent study led by Martyn Smith and published in the journal *Science* found that even lower exposures to benzene are associated with reduced blood cell counts and that people with certain genetic traits are particularly susceptible to benzene's toxic effects.

A research team led by Patricia Buffler is examining the links between leukemia risk and exposures to pesticides, metals, solvents, polychorinated biphenyls (PCBs), and polyaromatic hydrocarbons (PAHs). Buffler's team has found that indoor exposure to pesticides early in life may increase the risk

Estimated Tons per Year of Hazardous Air Pollutants by Potential Health Effects in California



Source: ARB, 2003. Reprinted from *Strategies for Establishing an Environmental Health Surveillance System in California.*

of developing childhood leukemia, which was the most common cancer diagnosis for children in the 25 years from 1973 to 1998.

Children are particularly vulnerable to environmental disease, including asthma, and the incidence of childhood asthma is increasing dramatically. Several studies have demonstrated a rise in the morbidity, mortality, and prevalence of asthma. One recent study attributed 30% of asthma exacerbations to environmental exposures. Research is also showing that prenatal exposures to environmental contaminants like secondhand smoke can increase the risk of childhood asthma.

While asthma is increasing significantly across all age groups, among children it is the leading cause of hospitalization and school absenteeism, and the most common chronic health condition. Asthma disproportionately affects residents of lower-income communities, who are more likely to live near factories and highways and are thus exposed to more air pollution. Asthma problems in these communities are compounded by the fact that residents often lack health insurance and generally have less access to preventive health care.

A New Tool

Environmental Health Tracking is the ongoing and systematic collection, analysis, and dissemination of information about environmental hazards and exposures, and the health effects that are potentially related to these exposures. An environmental health-tracking network would compile information about major pollutants, such as pesticides, industrial chemicals, and emissions. It would take into account stationary sources of pollution (such as factories and farms) as well as mobile sources such as cars, trucks, trains, and shipping. Using an innovative technique called geocoding, researchers can estimate the total exposure in a specific geographic area, such as a community, city, or county.

This ability to estimate geographically related exposure has immense value for scientific inquiry. It allows researchers to generate hypotheses about the relationships between pollution levels and people's health. A health-tracking network also allows researchers to monitor pollution levels over time and evaluate the effectiveness of policies intended to prevent or control pollution. Further, the tracking provides reliable information about potential health risks and thereby enables local residents to undertake their own prevention efforts.

Potential Benefits

As part of its planning efforts, the California Environmental Health Tracking Program (CEHTP) conducted a needs assessment with representatives of local health and environmental agencies and community-based and non-governmental organizations. The responses underscored the new program's potential. According to respondents, the information yielded by environmental health tracking can help communities:

- advocate for changes in land use policies
- track changes in air quality
- [track] changes in the health status of residents
- implement environmental justice policies in our communities.

> *"We would have a better sense of which chemicals or exposures to target and . . . stronger cases in pushing for progressive policies, either to phase out the worst chemicals or to push for safer alternatives."*
>
> Needs assessment respondent

Examples of Environmental Hazards for Tracking

- **Persistent Organic Pollutants**
  - PCBs and Dioxin
  - Polybrominated Flame Retardants
  - Phthalates
- **Metals**
  - Chromium
  - Lead
  - Mercury
- **Pesticides**
  - Carbamate
  - Organophosphorous
  - Organochlorine
  - Other Pesticides
- **Proposition 65 Chemicals**
- **Air Pollutants**
  - Criteria Air Pollutants
  - Hazardous Air Pollutants
  - Water Pollutants
  - Chemical Pollutants
  - Pathogens
- **Hazardous and Solid Waste**
- **Indoor Hazards**
  - Environmental Tobacco Smoke
  - Molds
  - Radon
  - Asbestos
  - Volatile Organic Compounds
- **Occupational**
  - Radiation
  - Lead
  - Other OSHA Hazards

Reprinted from *Strategies for Establishing an Environmental Health Surveillance System in California.*

West Oakland residents demonstrate against a source of pollution in their neighborhood.

Photos courtesy of the Pacific Institute.

Increasingly, people want access to local data, and they want to be involved in discussions of environmental health hazards. However, they have limited information about the health effects of exposures to environmental contaminants and about specific local hazards. Up to now, government agencies have poorly understood local needs. Local input is not comprehensively sought and local participation in statewide planning efforts has not been adequately facilitated.

Public health surveillance systems were developed with the assumption that researchers and government officials are the primary users of environmental and health information. The CEHTP needs assessment identified a much broader constituency.

"Community-driven environmental health research has led to many key victories in improving health and quality of life in communities that suffer the most."

Meena Palaniappan
The Pacific Institute

Meena Palaniappan of the Pacific Institute for Studies in Development, Environment, and Security in Oakland, California points out that "Community-driven environmental health research has led to many key victories in improving health and quality of life in communities that suffer the most. In West Oakland, putting research in the hands of residents led to the closure of the Red Star Yeast factory, the number one fixed source of toxic air pollution, leading the way for the development of a transit village in the community. Environmental health tracking puts residents in a powerful position to identify and solve problems in their communities and build safer, healthier places to live."

Essential Partners

Tracking uses current information sources, such as disease registries and environmental monitoring, but new data sources are needed to fill gaps in our knowledge. In addition, for an environmental health-tracking network to be effectively implemented, community needs must be considered—in planning, outreach, education, and capacity building.

A comprehensive data system depends on community partnerships. Community members can play useful roles in both collecting and using data. They have knowledge of local health risks and health problems. However, there is often a disconnect between the evidence that community members believe warrants action and the evidence that technical experts accept as sound science.

Good Science vs. Bad Science

When experts say that they base conclusions on sound or good science, they imply that policies should only be based on certain kinds of evidence. This approach undermines constructive partnerships with communities. First, it suggests that other kinds of knowledge are based on bad science. Second, it perpetuates the assumption that non-experts advocate positions based on ideology, not scientific evidence. As a result, a subtle division takes place, where some ways of knowing are accepted while others are marginalized.

Ronnie Neff and Lynn Goldman of Johns Hopkins University recently noted that pressures to adhere to "sound science" elevate the value of technical information above other values in decision-making.

While researchers point out that dioxin in the environment has not been linked to any particular health problems, community members believe the carcinogenic effects of dioxin shown in laboratory studies are sufficiently serious to warrant regulatory action.

This leads to the exclusion of the public, which in turn leads to both public distrust and the loss of potential public health safeguards. For example, insistence on "sound science" in assessing the health risks from dioxin, a byproduct of the manufacture of chlorine, has resulted in "almost 20 years of waiting for regulation…for a substance still classified as the most potent carcinogen."

Communities are looking for scientifically valid information on health and the environment. Where the public and professional sectors tend to differ is in the interpretation of scientific knowledge and its application to policy. For example, both researchers and community groups agree that emissions from power plants are a major source of mercury contamination in fish. Neither sector can yet prove that mercury poisoning caused Matthew Davis's illness. However, community groups are pursuing policy change to reduce what they conclude is a serious health risk. They are advocating for changes to the Clean Air Act to reduce contamination of an important food source.

Risk Assessment

The common framework today for environmental regulation is risk assessment. Risk assessors utilize information about the biological effects of chemical agents in models designed to quantify the probability of disease, generally cancer, resulting from exposure to a chemical agent. Regulatory action taken to reduce, eliminate or otherwise control exposure depends on predicted probability of harm. The combined effect of (1) limitations in knowledge about biological effects in human populations (data generally come from rats and mice), (2) lack of consideration about the combined effects of multiple chemical exposures, and (3) uncertainty resulting from the extrapolation procedures used in models, results in a high degree of uncertainty in predictions. Risk assessment is a tool for making consistent regulatory policy decisions, but it is clearly not an exact science. It is useful to keep in mind when setting policy that, as such, risk assessment is itself a social construct.

The Precautionary Principle

Community and non-governmental organizations in the United States, along with governments in Europe, have articulated an alternative policy framework for addressing environmental health hazards. Known as the precautionary principle, it is based on the conclusion that risk assessment is an inadequate tool for assessing the effects of simultaneous exposure to hundreds of known toxic compounds. Jeanne Rizzo, executive director of the Breast Cancer Fund, notes that, "while we cannot possibly track everything and … there will be limitations of science, … we can, as citizens of this planet, parents, partners, and friends, call for the paradigm shift that will serve the next generation—one of precaution, rather safe than sorry, do no harm."

Policies based on the precautionary principle are supported by science, as are policies based on risk assessment. Communities and local governments are embracing this new policy framework due to frustration over increases in chronic diseases, such as asthma, that are strongly associated with environmental exposures. However, current efforts advocating the formal adoption of the precautionary principle are viewed by some as leading to costly regulatory action without sufficient scientific basis.

Communities and local governments are embracing a precautionary policy framework due to frustration over increases in chronic diseases, such as asthma, that are strongly associated with environmental exposures.

Precaution Isn't New

In 1964, the U.S. Surgeon General issued a precedent-setting report calling for action to reduce tobacco smoking, despite the lack of absolute causal evidence linking smoking to lung cancer. The Surgeon General convened an Advisory Committee to examine the available evidence on smoking and lung cancer; their report concluded, "Cigarette smoking is a health hazard of sufficient importance in the United States to warrant appropriate remedial action."

Environmental health advocates suggest that this precedent should be applied to other exposures of concern, and there are some indications of change. In 2003, California passed a law to phase out products containing PBDEs (polybrominated diphenyl ethers) flame retardants beginning in 2006. High levels of PBDEs have been found in wildlife, women's tissue and breast milk, raising concern about potential long-term damage to children's brains during pregnancy.

Prescription for Change

The assumption that technical knowledge and policy action is strictly the domain of scientific experts leads to the marginalization of differing points of view. Recognizing the validity of multiple points of view, both technical experts and laypersons are seeking ways to collaborate effectively.

Resist false dichotomies. The creation of dichotomies is reinforced in many social contexts. Dichotomies are frequently used in political discourse, for example, to define opposition. However, they oversimplify issues and breed resentment and distrust. We need to avoid creating a dichotomy between policies based on risk assessment and policies based on precaution. Both approaches have a scientific basis; both offer valid rationales for taking action. And when we rely only on a risk assessment approach we often miss health problems at earlier stages, when prevention is still possible.

Embrace ambiguity. Environmental problems are social constructs informed by social values as well as science. How we conceive a problem will define the solutions we seek. Thus, many people believe that sustainable solutions must be developed through broad policies, such as those designed to encourage clean energy and green production processes.

Allow for complex solutions. A good or effective solution can accommodate many perspectives on the problem. We need to trust that the process will support the best solution for any particular problem and take into account the importance of the problem's social context.

For example, we issue a fish advisory to address the problem of people eating mercury-contaminated fish. However, we could, with equal validity, define the problem as the lack of clean energy and green production processes in power plants and mines. This construction of the problem does not diminish the value or need for a fish advisory, but it serves to articulate an "up stream" and sustainable solution to an exposure of concern.

For this to happen, it is important that technical experts recognize the legitimacy of a focus on the primary sources of pollution, not just a specific chemical or compound as it shows up in a food or place.

Recognize diverse values, especially when setting policies. Technical expertise is a good thing, but should not be placed above other human values, including the value placed on a non-harmful environment. Technical knowledge is one kind of knowledge that can help stakeholders define issues. Professionals such as regulators may be required to apply a specific scientific approach. But when it comes to creating policy, it is important to consider other kinds of expertise.

Create open dialogue. Technical experts often feel compelled to respond to every issue that emerges in a discussion, and they may be so focused on the technical content that they fail to hear people's stories and values. Using a facilitator or otherwise delegating control of a dialogue can help create an atmosphere where everyone's voice is heard. Stakeholder participation should not be used to confer a stamp of approval on a "cloaked" predetermined position. Participatory action is an art.

Develop tools for clear communication. We need to develop a common and understandable language for discussing environmental health issues and sharing data and research results. Communities need and want technical assistance to help them understand and use environmental health tracking data, and experts need to find ways to communicate technical information to the general public.

A Common Goal

Both community members and technical experts are stakeholders in the fight to reduce disease. Both need better information on environmental health hazards. We need to work together to analyze and disseminate this information, so that we can take action to prevent illness. The ability to act on early warnings is a fundamental goal of environmental health tracking: to identify and mitigate risks, such as the high concentration of toxins that may have contributed to the premature death of Leslie Guttierez's twins and compromised Matthew Davis's central nervous system. Informed and involved communities can play a critical role in alerting scientists to emerging problems, in defining issues and generating data, and in developing policy interventions that prevent —not just treat—disease.

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CDC National Environmental Public Health Tracking Program: www.cdc.gov/nceh/tracking/

California Environmental Health Tracking Program: www.catracking.com

Health Research for Action Center

perspectives

About the Center

Health Research for Action—formerly the Center for Community Wellness—is a center in the U.C. Berkeley School of Public Health. Our mission is to conduct and translate research into successful resources and programs for the public to reduce health disparities and create more hopeful, empowered communities. This issue of *Perspectives* was produced in collaboration with the Berkeley Center for Environmental Public Health Tracking

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Progress in Pediatric Asthma Surveillance I:
The Application of Health Service Utilization Data for Asthma Surveillance

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Word counts:

Abstract: 249

Text: 4,054

Progress in Pediatric Asthma Surveillance I:
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Key Words: Asthma, Community pediatrics, Health disparities, Health information, Methodological issues

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Abstract

Objectives. The ability to conduct community level asthma surveillance is increasingly crucial for public health programming and child health advocacy. We explored the potential and limitations of health service utilization records from both public and private sources for the purposes of asthma surveillance.

Methods. We combined administrative patient record data from Kaiser Permanente of Northern California and the California Medicaid program for Alameda County residents during 2001. We assessed the resulting dataset for completeness, population representation, consistency with external data, and internal indicator consistency.

Results. Our resulting dataset included records for 226,383 children <18 years of age, or one of every two children in the county. Completeness of Medicaid data was greatly affected by managed care market share, reducing our usable dataset size to 176,783. External data documenting hospitalization rates due to asthma were correlated with hospitalization rates (r=0.2861, p=0.0817) and emergency room visits (r=0.8233, p<0.0001) in the administrative dataset. High internal consistency of indicators suggested that the dataset represented a broad spectrum of health care access and quality of care congruent with clinical aspects of the disease.

Conclusions. The utility of these data are heavily influenced by logistical and administrative factors, including the health care payment structure and the market shares of care providers. Our ability to generate county-level health statistics for comparison to other locations was limited, although the dataset appeared well suited for within-county

geographic analysis. In light of these findings, these data can be expected to greatly expand the local health surveillance capacity of communities.

Progress in Pediatric Asthma Surveillance I:
The Application of Health Service Utilization Data for Asthma Surveillance

Although asthma has emerged as a major public health challenge,[1] our current needs for asthma surveillance in populations far outstrip our abilities. In a sense this problem comes as no surprise, given that there is no single test or entirely objective definition for either the disease or its resolution.[2-4] Historically, surveys of patients and parents have formed the backbone of asthma surveillance. Cultural differences and inconsistencies in reporting,[5-8] however, as well as the high cost of survey studies,[2, 9] make such methods problematic for the purposes of ongoing monitoring. At the national level, asthma surveillance takes the form of a patchwork of surveys reporting symptoms, diagnoses, Emergency Room and clinic visits, and hospitalizations.[1, 10] A small number of states have made steps towards asthma surveillance as well.[11-13] Over the past several years a consistent picture has emerged of generally rising morbidity and stark social disparities in the disease, but the causes both of the spread and the disparities remain controversial.

Increasingly, childhood asthma prevention and management has become a state and local issue, as state health care expenditures have increased and individual communities have focused on the impacts of the disease on school districts, local economic development, and questions of environmental justice.[14-17] Communities seek local disease surveillance data to enable them to assess small-area variations in asthma rates, to identify sub-populations at risk, and to plan health resource allocation; however, such data are generally scarce.[18, 19] As asthma is increasingly recognized to be tied to issues of neighborhood segregation, local air quality, and the distribution of health resources, the demand for local surveillance of the disease can be expected to intensify.

As part of the CDC-funded California Environmental Public Health Tracking Program (CEHTP), we collaborated with a private health care provider, Kaiser Permanente of Northern California, the State Medi-Cal Program (California's version of Medicaid), and an array of community based and nongovernmental organizations to develop asthma surveillance that would meet the needs of stakeholders in Alameda County, a mostly urban county in the metropolitan San Francisco Bay area. We were interested in our ability to generate high-quality data that (1) generally represented the County population, (2) provided a complete picture of the geography of asthma using a broad array of asthma-related health events, and (3) included patient addresses of residence to enable high-resolution geographic analysis.

The use of health service claims for comprehensive monitoring of asthma morbidity, health care access, and management has been underscored by several authors as an important next step,[20, 21] although few[13, 22-24] have described the possibilities, pitfalls, and limitations of such work in detail. Our process of evaluating the utility of health service utilization data for asthma surveillance is described below, followed by discussion of the logistical and administrative factors affecting data utility. Technical and statistical procedures for data analysis and visualization are described in the following article,[25] which is a companion to this one.

Using health service records for asthma surveillance

Analysis of hospitalization rates to reflect the burden of asthma in populations is a long-standing practice,[26] although it carries several limitations. Among children, only those with severe and/or poorly controlled asthma are hospitalized, which means that hospitalization rates are confounded by differences in access to care among populations.[10] Furthermore, hospitalization is a comparatively rare event relative to overall disease prevalence, so small-area rates are usually difficult to calculate with any precision. Some epidemiologists have utilized three-year averages to gain statistical stability at the ZIP code level, but this appears to be the limit of geographic resolution for hospitalization data.[27] Oyana and collegues[28] were able to analyze clustering of asthma hospitalizations around the Peace Bridge complex in Buffalo, NY by aggregating five years of such data.

Several investigators have explored the use of billing records for asthma surveillance, which promises several advantages. Particular interest has centered on the possibility that health service events besides hospitalization, such as Emergency Room visits, outpatient visits, and medication purchases may be available for surveillance purposes, which can greatly expand the pool of people identified as having asthma. In populations with good access to care, one would not expect mortality, hospitalizations, and ER visits to be elevated even in the face of a relatively high prevalence of asthma[29] (Figure 1). Similarly, among populations with poor access to care, one would expect these indicators to be elevated out of proportion to the actual asthma prevalence. The hope is that, by assessing the rates of lower acuity or routine events, a more complete picture of asthma in geographically defined populations may be constructed.

Some efforts to evaluate the utility of billing records for asthma surveillance have taken place in Canada.[30] A few studies have also used insurance claims data for the study of occupational disease.[31-33] A group of investigators in Milwaukee[23] sought out records from area hospitals, clinics, and HMOs to estimate asthma burden. They were able to monitor both Emergency Room and outpatient visits (in addition to hospitalizations) for asthma in a relatively low cost, potentially sustainable manner.

Other researchers have attempted to use medication-purchasing patterns to construct indices of asthma in populations. This approach is consistent with U.S. national guidelines which explicitly include medication use when classifying asthma severity.[29] Again, a Canadian group was able to roughly classify patients with respect to the severity of their asthma using medication records,[24] although they caution that such an approach in the United States would be confounded by differences in health care access among populations. A North Carolina group examined health care utilization, including medication purchasing, among Medicaid beneficiaries and were successful in quantifying prevalence by age, race, and rural/urban residence.[34] Consensus is growing that medication-purchasing information is an important component of records-based asthma surveillance that requires development.[10, 26]

All of the above studies have cited the need for comprehensive indicators of asthma burden beyond hospitalization rates as a motivation for investigating the use of health service billing records. Curiously, none mention an additional advantage related to the use of such records—the availability of patient address data to enable surveillance of asthma in small geographic areas. Advances in geographic coding, spatial statistics, and geographic information visualization have made possible the calculation and presentation of disease rates at sub-ZIP code resolution while preserving patient confidentiality.[35]

Evaluating health service records for surveillance purposes

For the present study, we evaluated the utility of health service records from public and private sources for monitoring asthma among children. We were particularly interested in the feasibility of using these data to meet the surveillance needs of local stakeholders, which included quantifying and visualizing health disparities, identifying populations at elevated risk for asthma, and informing discussions of environmental justice by linking them to broader population health issues.

To evaluate this feasibility, we constructed a working dataset for Alameda County, a diverse, urban county of Northern California of 1.4 million residents. We examined (1) data completeness, (2) the resulting population representation, (3) the external consistency of the data with the previously understood distribution of asthma in Alameda County, and (4) the internal consistency of the indicators with each other.

Materials and methods

Data sources. Health services data were drawn from two sources. The first was Kaiser Permanente of Northern California (KPNC), an integrated healthcare delivery system which is the region's largest single provider of health services. Out of the total 3.1 million members of KPNC, 577,687 were residents of Alameda County in 2001; approximately 40% of county residents received their care at KPNC during that year. Kaiser Permanente has been a pioneer in medical information technology, maintaining a complete list of enrollees (denominator data) and databases describing hospitalizations, clinic visits, referrals, external claims, and medication purchases by members (numerator data) and utilizing these for both administrative and health services research purposes (for examples, see references[36, 37]).

The second source was Medi-Cal, the state Medicaid program, which covered 227,086 beneficiaries in Alameda County during the study year of 2001. Medi-Cal as a data source is complicated, however, by the fact that since 1994 the state has begun subcontracting patient care through managed care (HMO) organizations. As of 2001 in Alameda County, all patients qualifying for zero share-of-cost Medicaid benefits were required to enroll in one of the two managed care plans in the county, Blue Cross of California or Alameda Alliance for Health (other beneficiaries are given the option to join). We investigated the reporting rates of health utilization events by the managed care organizations to the state Department of Health Services in Sacramento by comparing them to event rates under the fee-for-service arrangement. Finally, a small portion of Kaiser Permanente enrollees (1.7% of the total; 3.2% of children) are also Medi-Cal patients subcontracted through the Alameda Alliance for Health (Figure 2).

We compared these data to hospitalization counts abstracted by the California Office of Statewide Healthcare Planning and Development (OSHPD). These data are reported by hospitals to OSHPD as required by law and represent 100% counts of hospitalizations around the state. Although hospitalizations are the only asthma-related "event" recorded by OSHPD and the patient's ZIP code of residence is the sole geographic field available, these data are the nearest thing to a "gold standard" to which we can compare numbers generated from the Kaiser Permanente and Medi-Cal datasets.

Defining asthma "events." Hospitalizations, Emergency Room visits, and outpatient visits in the datasets included fields for primary and (in certain cases) secondary diagnoses. For comparisons to existing datasets, such events were considered asthma-related if the primary diagnosis began with the digits "493," the ICD-9 code for asthma. For the purposes of health surveillance, however, we included the aforementioned events, plus those having asthma as the secondary diagnosis and a primary diagnosis of “pneumonia,” “respiratory failure,” or another condition for which an asthma exacerbation was likely to be the cause.

We classified medications as asthma-related based on their functional class and divided them into “symptom” (“rescue”) and “maintenance” (“controller”) medications. Symptom medications included long- and short-acting beta agonists and anticholinergics, while maintenance medications included antileukotrienes, mast cell stabilizers, methyl xanthines, and inhaled corticosteroids. (These last could be present alone or in combination with bronchodilating agents). Oral corticosteroids were omitted out of concern that their use for reasons other than asthma was commonplace enough to compromise the specificity of the indicator. It was later noted that this classification algorithm is identical to that constructed independently by Buescher and Jones-Vessey.[34]

Statistical analysis. For questions of data completeness, straightforward frequency analysis was all that was required for analysis. Assessment of population representation used frequency analysis preceded by the coding of each patient to his or her census tract of residence, roughly following the methods of Krieger.[38] For questions of consistency of indicators with external data sources and among each other, bivariate correlation analysis was applied to data aggregated to the ZIP (postal) code and census tract levels, respectively. For the former, we calculated the Pearson correlation coefficients between the OSHPD ZIP code-level hospitalization rates and the Kaiser Permanente hospitalization rates, the Medi-Cal fee-for-service rates, both combined, and the

Emergency Room visit rates from both combined. For all analyses, we used SAS version 8.02 (SAS Institute, Cary, NC).

Results

These data combined to represent 226,383 children under 18 years of age, or 2.3 million person-months of information. Usable sample size was subsequently reduced in light of data quality considerations, which are discussed below.

Data completeness. The hospitalization rate calculated for fee-for-service Medi-Cal appears highly consistent with that calculated using the OSHPD data (Figure 3). Both managed care subcontractors in the county, however, reported hospitalizations at a substantially lower rate than either of these sources. Managed care rates of ER visits, outpatient visits, and medication purchases also consistently amounted to a small fraction of those calculated using fee-for-service Medi-Cal. For this reason, subsequent analyses excluded the managed care Medi-Cal population, reducing the total sample size to 176,783 children, or 1.7 million person-months.

Population representation. Comparison with fee-for-service beneficiaries revealed that managed care enrollees were more likely to be under 18 years of age (61% versus 21%), and among children, they were more likely to be enrolled in Medi-Cal for the entire 12 months of the year (55% versus 19%). For Kaiser Permanente data, we coded each enrollee to their census tract of residence. In this manner, we could estimate the proportion of the sample in each income stratum and compare these figures to those for the overall population using year 2000 U.S. Census data. The enrollee population shows high congruence with the socioeconomic profile of the county as a whole, although it slightly under-represents populations on either extreme of the continuum and over-represents those in the middle (Figure 4).

Consistency with external data. We assessed the validity of our data through comparison to the OSHPD dataset, from which were available hospitalization rates due to asthma by ZIP (postal) code aggregated over the years 1998-2000. Both data sources combined to produce a picture of the geographic distribution of asthma hospitalizations more consistent with the external dataset ($r = 0.2861$, $p = 0.0817$) than either one alone (Table 1). Among the county's health care providers, Kaiser Permanente hospitalization rates tend to be low (approximately 50% of the county-wide rate in 2001); we believe that this situation prevented the correlation from being any higher. Rates of Emergency Room visits for the two datasets, however, were much more highly correlated with OSHPD asthma hospitalizations ($r = 0.8233$, $p < 0.0001$). Thus, ZIP codes with high OSHPD asthma hospitalizations also tended to have high ER visits as contained in our datasets, which is consistent with the notion that these areas may have more severe and/or poorly cared-for asthma.

Internal consistency. We posited that the quality of care "profile" of each census tract within the county would fall along a spectrum of access and quality of care similar to that shown in Figure 1. Pearson's correlation coefficients between the health services indicators at the census tract level are shown in Table 2. The indicators closest to one-another on the spectrum of care (such as hospitalizations and ER visits) are indeed the most highly correlated, while those farther apart (such as hospitalizations and maintenance medication purchases) are progressively less correlated with each other.

After removal of incomplete records, the dataset described a total of 311,774 asthma related health events, not including hospitalizations. The numbers for each event type are shown in Table 3.

Discussion

In this study, we evaluated the use of routinely collected health utilization data which could be used for an ongoing asthma surveillance system in California. By focusing on administrative care utilization data from private and public sources, we were able to make available a range of asthma indicators much broader than our previous reliance on hospitalization data alone. The use of these databases also provides an additional advantage for surveillance as patient data is available down to the home address level. We assessed the quality of the assembled data for completeness, population representation, consistency with external sources describing the distribution of asthma morbidity in the county, and internal consistency of the indicators with each other.

Data completeness. We knew at the outset that data completeness would be most open to question concerning the state (Medicaid) data, and analysis showed that the key determinant of completeness was the degree to which the beneficiary population was enrolled through managed care versus fee-for-service systems. For Alameda County in 2001, fee-for-service enrollees had complete data through the state office in Sacramento, while managed care enrollees did not. This finding has important implications for the development of asthma surveillance systems using Medicaid data, since 48 of the 53 U.S. states and territories with Medicaid programs utilize capitated managed care plans, with enrollment ranging from less than 10% up to 100% of the Medicaid population.[39] The total proportion of Medicaid enrollees served through managed care plans has risen from

40% in 1996 to over 60% in 2003,[40] and while some states have a uniform set of managed care options for all enrollees statewide, some (including California) vary by county.[41] Under these arrangements, routine reporting of health care events and centralization by the state program is more likely to be incomplete or absent than under traditional fee-for-service systems.

Population representation. Medicaid data provide a picture of health care utilization for the county's lowest income residents; our interest in working with Kaiser Permanente data, in contrast, stemmed from the possibility of representing the utilization by a broad spectrum of socioeconomic strata. Consistent with the findings of Krieger in 1992,[38] we noted that the Kaiser Permanente data performed this role well, although they slightly under-represented those at either extreme of the spectrum and slightly over-represented those in the middle. As with our findings regarding the completeness of Medicaid managed care data, these findings should be expected to vary by county in California, since multiple managed care entities control varying portions of the state health care market by region.

Our ability to assess the degree to which the fee-for-service portion of Medi-Cal population was representative of the entire Medi-Cal population was limited. Racial and ethnic data recorded by Medi-Cal, when collected, are considered unreliable, although we could discern that managed care beneficiaries were more likely to be children, and among children they were more likely to be longer-term beneficiaries. The process by which Medi-Cal beneficiaries are assigned to managed care or fee-for-service plans is complex, with choice of assignment contingent upon the administrative mechanism of eligibility. This finding suggests that episodic enrollment is more common among fee-for-service beneficiaries, and that enrollment in managed care plans increases with the duration of eligibility.

Overall, the non-random nature of the study sample is a major issue, and it precludes the calculation of county-wide asthma-related health care utilization rates for comparison to state or national figures. On the other hand, fully 1 of every 2 child residents of the county is included in the dataset, or 1 in 3 if the figure is calculated using person-months. Because of this fact and the finding that the dataset had high external validity, it was felt that the dataset was still useful for within-county sociodemographic and geographic comparisons.

External validity. Our ability to mirror the geographic patterns known from the OSHPD "gold standard" dataset using the health service event datasets could not be taken for granted. On one hand, we had a private managed care dataset with high overall population representation, but with a population for whom hospitalization rates (but not Emergency Room visits) were known to be lower than the county-wide average. On the other hand, we had a public payer dataset restricted to the lowest-income communities in the county, communities also known to experience a disproportionate share of hospitalizations due to asthma. It was not clear whether one of these datasets or the other, or both datasets combined, would most accurately reflect the overall geographic distribution of asthma events.

We found that (a) the combination of Medi-Cal and Kaiser Permanente patient records generated a geographical pattern more consistent with the OSHPD data than either set of records could alone, and (b) that ER visits were tightly correlated with hospitalization rates from OSHPD data while the hospitalizations themselves in our dataset were not. This finding came in spite of the fact that hospitalization rates and Emergency Room visit rates, being separate phenomena, might not be expected to match each other precisely. Since both hospitalizations and ER visits can be expected to reflect the distribution of severe, poorly-controlled asthma in the county, however, it is logical that the geographic variations of each should correlate somewhat. Furthermore, Kaiser Permanente, as a centrally coordinated managed care organization, is able to “steer” patients away from hospital admissions by encouraging extensive Emergency Room management and implementing case management strategies, in the interests of both cost-savings and quality of care. Since our hospitalization rates are numerically driven by the Kaiser Permanente patients, it makes sense that our hospitalization rates, but not our ER visit rates, would be depressed relative to the county-wide numbers form OSHPD. Therefore for further analytical purposes,[25] we focused on Emergency Room visits as our indicator of poorly-controlled asthma and excluded hospitalizations.

County-wide, rates of other asthma-related health service use were largely consistent with national data. Emergency Room visit rates based on the National Ambulatory Medical Care Survey (NAMCS)[42] for this age group are very close to those found in this study population. Medication purchasing rates reported from the Medical Expenditure Panel Survey[43] are also consistent with this population, although the Alameda County population appears to purchase a greater proportion of maintenance medications than would be expect from the national numbers. Outpatient visit rates were also substantially higher in the Alameda County population than would be expected based on the national NAMCS numbers.[42]

Internal validity (consistency). The high degree of internal consistency of the health utilization indicators noted in this dataset reinforced our view of these indicators as representing various positions on a spectrum of asthma quality of care (Figure 1). Specifically, events that would be expected to occur together (such as hospitalizations with ER visits or symptom medication purchases with maintenance medication purchases) did indeed do so, and events associated with different standards of asthma primary care (such as hospitalizations and maintenance medication purchasing) did not. The ability to reflect this spectrum of care quality was one of the major objectives for developing these datasets because of stakeholder interest in comprehensively representing the problem of asthma in the county.

Other measures of data utility. Other authors have also discussed attributes for the assessment of data sources for health surveillance purposes.[44] These include quantitative attributes such as sensitivity (completeness), representativeness, validity, and timeliness, as well as qualitative ones such as simplicity, acceptability, and cost. We directly assessed all of the qualitative attributes in the present study except for timeliness. Medi-Cal encounter data has typically taken an average of four months for processing prior to becoming centrally available through the Medical Care Statistics Section offices in Sacramento, although the speed of this process appears to be improving. One problem with receiving data is the time needed to clean the data for quality assurance purposes. Sacrifices in data quality may be necessary in order to increase the value of the data for surveillance with the understanding that surveillance data results are preliminary. Similarly, it is the experience of the Kaiser Permanente of Northern California Division of Research that a lag-time of approximately six months is required prior to the availability of complete patient encounter data. This provider is currently developing a comprehensive electronic medical record system, however, which is expected to move most data acquisition capacity to near real-time.

External factors affecting data quality. The potential to adapt these data sources for surveillance, particularly outside of the demonstration area of Alameda County, is affected by a number of issues. One of the primary requirements for this approach to be adopted elsewhere would be the ability to incorporate private sources of data which represent a large market share of health service coverage in that location. Similarly, the proportion of Medi-Cal data which is fee-for-service or managed care varies by county. Automated geocoding and address verification systems which were developed for this project could be used in other counties to make the entire analytic process more efficient. Similarly, the adoption of data standards by all Managed Care entities would be of great value for surveillance purposes. With collaborations between private local providers of health utilization data, the cost for data could be minimal. However, there are additional costs for data processing, data visualization and analysis, hardware, software, personnel, and for data dissemination.

Conclusions

We constructed this working dataset with the goal of increasing asthma surveillance capacity to facilitate clinical and public health interventions. For two reasons, the result represents a substantial step forward in this regard. The first is the fact that we were able to incorporate a broad range of indicator variables related to asthma into a single dataset with ample statistical power (Table 3), meeting a need expressed by several authors.[10, 24, 26] Furthermore, because of the availability of patient address data, we enable high-resolution geographic analysis of asthma in the county, as demonstrated in the companion article to this one.[25] Through this activity, we are able to identify subpopulations facing increased vulnerability to asthma and barriers to care, quantify racial and socioeconomic disparities in patterns of asthma care, and formulate hypotheses regarding local sources of pollution or other environmental contributors to the burden of disease.

Acknowledgements. This work was supported through a grant from the Centers for Disease Control and Prevention (#U50/CCU922449).

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Table 1. Correlations of childhood asthma hospitalization and emergency room (ER) rates from surveillance datasets with "gold standard" county-wide childhood asthma hospitalizations,[a] Alameda County, California.

	r	*P*
Hospitalizations (Kaiser Permanente only)	0.2124	0.2779
Hospitalizations (Medi-Cal fee-for-service only)	-0.2681	0.2981
Hospitalizations (both sources combined)	0.2861	0.0817
ER visits (both sources combined)	0.8233	<0.0001

[a]Office of Statewide Healthcare Planning and Development (OSHPD) 100% hospitalization dataset, ages 0-14 years, 1998-2000

Table 2. Internal consistency of indicators. Pearson's correlations, *p*-values, and numbers of census tracts included in the calculation are shown within each cell. Cells showing correlations between health events are shaded according to their degree of logical proximity as described in Figure 1.

	Hospital-izations	ER visits	Outpatient visits	Symptom medication purchases	Controller medication purchases
Hospital-izations	1.0000 262	0.5980 <0.0001 262	0.2331 0.0001 262	0.0893 0.1495 262	0.0049 0.9372 262
ER visits		1.0000 302	0.4072 <0.0001 302	0.2213 0.0001 302	-0.0266 0.6447 302
Outpatient visits			1.0000 321	0.5197 <0.0001 302	0.4061 <0.0001 321
Symptom medication purchases				1.0000 321	0.7448 <0.0001 321
Controller medication purchases					1.0000 321

Table 3. Asthma-related health service events available for health surveillance through combined working dataset.

Event	Total
Hospitalizations	0[a]
ER visits	3,579
Outpatient visits	53,611
Purchases of symptom medications	160,029
Purchases of maintenance medications	94,555

[a]Not used due to poor external validity.

Figure Legends

Figure 1. The spectrum of health service indicators for asthma by quality of care.

Figure 2. Administrative sources for health service billing records in Alameda County, California. Shaded circles indicate enrollee populations able to be included in the analysis because of completeness of records. Approximately 3.9% of Kaiser Permanente person-months represent Medi-Cal beneficiaries subcontracted through Alameda Alliance for Health.

Figure 3. Hospitalization rates due to asthma (primary diagnosis only) among Medi-Cal beneficiaries during in Alameda County, California, by source of data. OSHPD includes 100% of county residents receiving Medi-Cal benefits; the other three data sources include only their respective portions of this population. OSHPD rate is calculated for children aged 0-14 years; all other rates are for ages 0-17 years.

Figure 4. Population representation of Kaiser Permanente enrollee population, Alameda County, California, 2001.

Progress in Pediatric Asthma Surveillance I:
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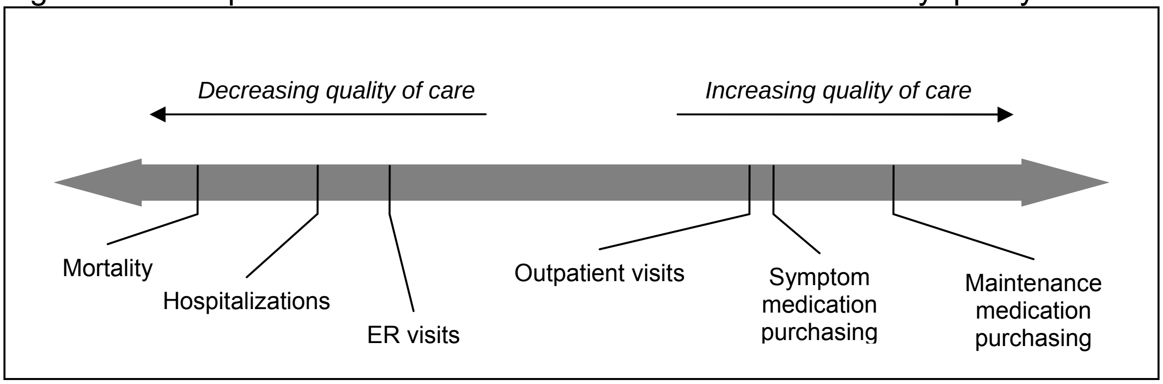
Figures

Figure 1. The spectrum of health service indicators for asthma by quality of care.



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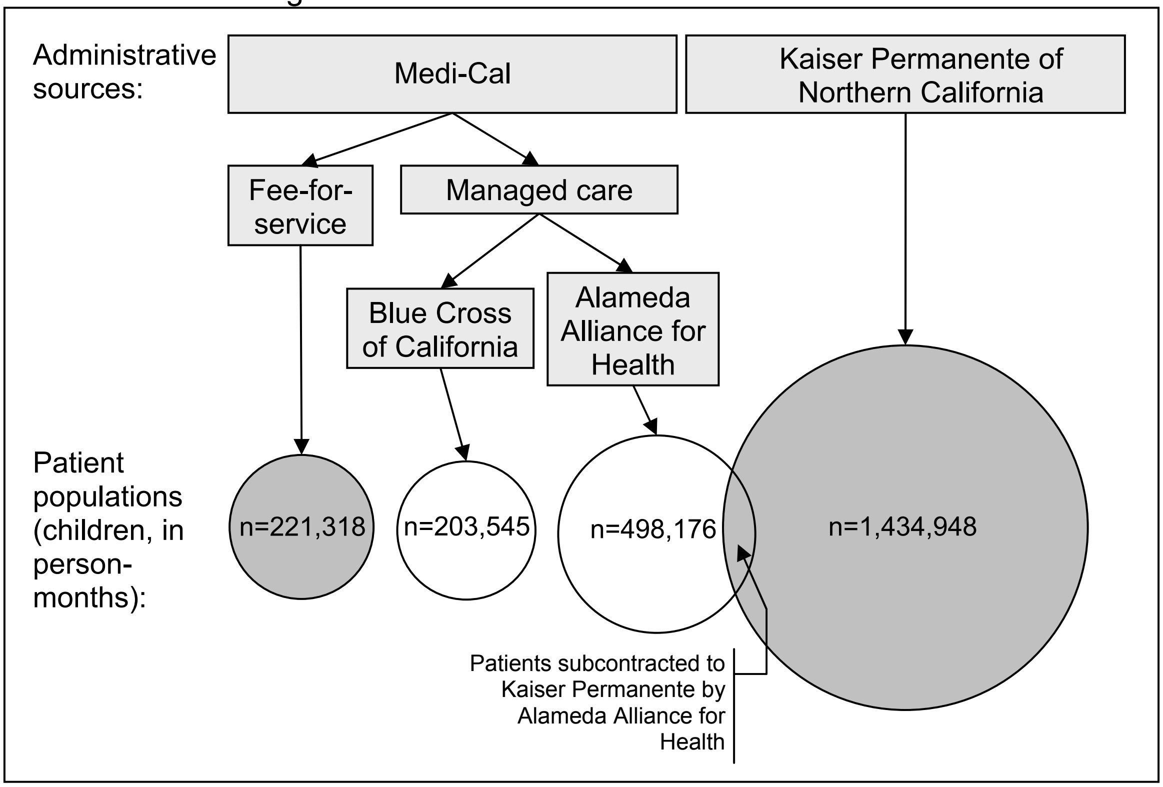

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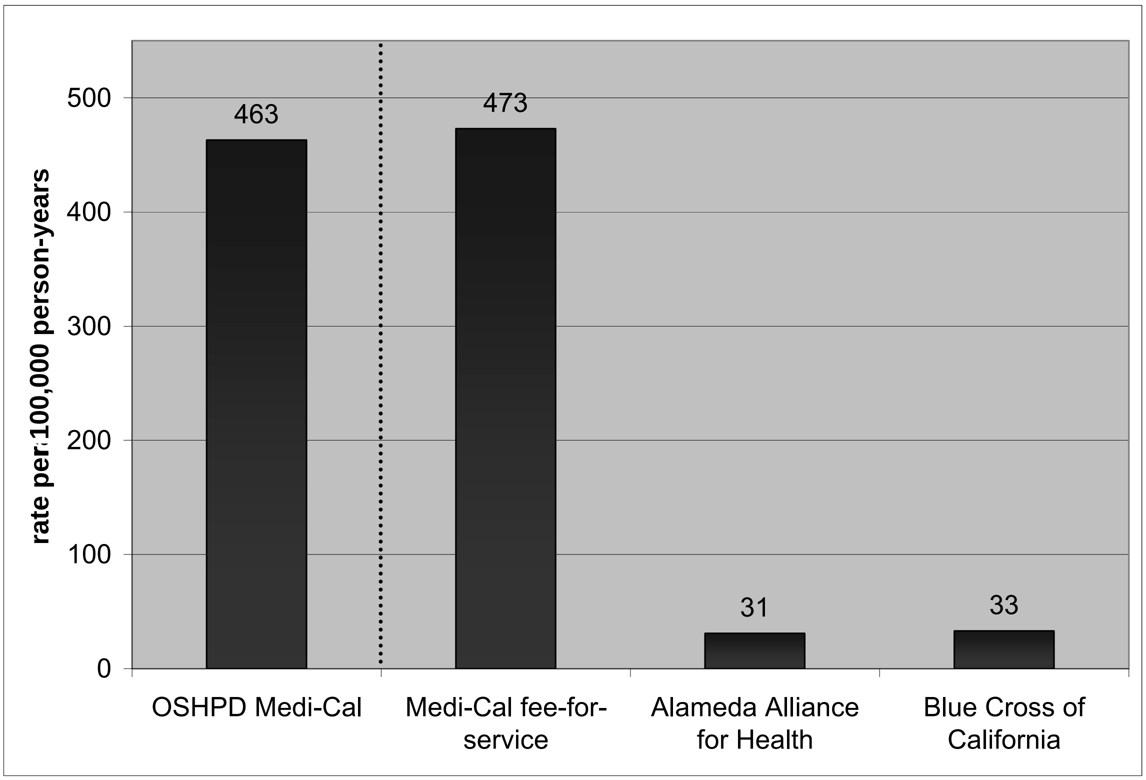
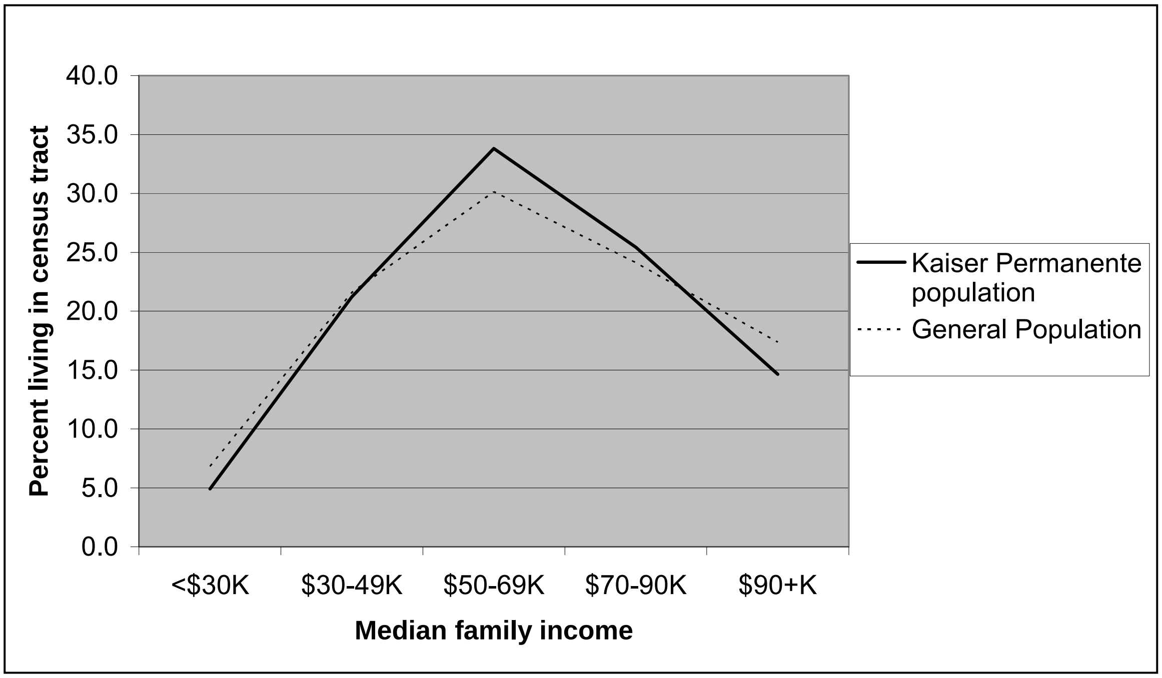


Figure 4. Population representation of Kaiser Permanente enrollee population, Alameda County, California, 2001.



Progress in Pediatric Asthma Surveillance II:
Geospatial Patterns of Asthma in Alameda County, California

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None of the above authors has any affiliation, financial agreement, or other involvement with any company whose product figures prominently in the submitted manuscript, or any other conflict to interest regarding this manuscript.

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Word counts:

Abstract:	244
Text:	3,938

Progress in Pediatric Asthma Surveillance II:
Geospatial Patterns of Asthma in Alameda County, California

Key Words: Asthma, Community Pediatrics, Health Disparities, Health Information, Methodological Issues

Progress in Pediatric Asthma Surveillance II:
Geospatial Patterns of Asthma in Alameda County, California

Abstract

Objective. To develop high-resolution asthma surveillance techniques responsive to the needs of health service professionals and local child health and social justice advocates.

Methods. We assembled a working dataset of health service utilization records from public and private sources covering 2.3 million person-months among children under 18 years of age in Alameda County, California. Health services were categorized by type and analyzed by census tract demographic information. Images of the geographic distribution of health service events were created using density estimation mapping with overlapping 0.5-mile (805-meter) radius spatial buffers, and statistical significance (two-tailed $p<0.05$) was estimated using a Monte Carlo simulation algorithm.

Results. High-poverty communities had elevated rates of Emergency Room visits due to asthma compared to low-poverty communities; this relationship was reversed as one considered indicators of progressively higher quality of asthma care ($p<0.05$). Geospatial analysis enabled visualization of this phenomenon; it further detected areas with elevated Emergency Room visit rates in and around specific communities of concern and potentially related environmental hazards. Areas of the county not previously considered to be deeply burdened by asthma were identified.

Conclusions. The assembly and high-resolution geospatial analysis of health utilization data contributed to a fuller understanding of pediatric asthma for community members, public health professionals, and clinicians. Information generated using these

techniques facilitated rich discussion among stakeholders of the environmental and social contexts of asthma and health disparities in general. Process evaluation suggested that we were able to effectively communicate this information to local stakeholders.

Developing tools for asthma surveillance

As with many diseases, the epidemic of asthma among children over the past few decades has been shaped by a social and environmental context that is becoming progressively more evident. The disproportionate burden of the disease borne by low-income communities and communities of color has long been noted.[1-3] Increasing evidence that the disease and its consequences are influenced by both access to health care[4-6] and environmental exposures[7-10] have contributed to the formulation of asthma as a social and environmental justice issue.[11, 12] As communities mobilize resources around the problem of asthma, considerations such as economic parity, the built environment, segregation, housing quality, and local sources of pollution have become at least as prominent as questions related to the clinical management of the disease.[13-17]

For these types of discussions, however, commonly used methods for asthma surveillance have only limited utility. Much of our knowledge regarding asthma prevalence and disparities is based on nationwide surveys such as the National Health Interview Survey, the National Health and Nutrition Examination Survey, the National Ambulatory Care Survey, and the Behavioral Risk Factor Statistical Survey.[18] Counties and local organizations for which local data are important, however, must frequently rely on inference when applying these general findings to their communities of interest.[19, 20]

The cost and complexity of population-based health surveys places such activities beyond the reach of most communities,[21, 22] so they generally rely on hospitalization rates due to asthma to quantify the problem in their local areas. Because of the large sample sizes required to calculate such rates, data must generally be aggregated over multiple years, and under the best of circumstances are likely to be available only at the level of the ZIP (postal) code.[23-25] While helpful, such data are of limited use for advocates seeking to target limited resources and generate awareness around specific environmental determinants such as roadways, ports, or industrial facilities for the following reasons:[26]

- Hospitalization rates reflect only the most severe, poorly controlled asthma;
- Communities of concern are often smaller than ZIP codes or cross ZIP code boundaries, which requires higher resolution for health surveillance;
- Gradations of health risk are represented as abrupt changes at ZIP code boundaries when traditional mapping techniques are employed; and
- Large, thinly populated areas, although lacking in valid data due to the instability of calculated rates, convey the greatest visual impact.

As part of the California Environmental Health Tracking Program (CEHTP), we sought to develop techniques for disseminating asthma surveillance information that are responsive to community needs. Databases were assembled containing geocodable information describing health services use related to asthma, a process described in the accompanying article. Here we describe the analysis of this database along with subsequent results and their potential contributions to local efforts to respond to the asthma crisis.

Asthma in Alameda County, California

Alameda County is a largely urban county in the San Francisco Bay Area with a population of approximately 1.4 million. A large diversity of socioeconomic strata and ethnic groups is represented in the county, and fully 27.1% of residents were born outside of the United States. Of these immigrants, approximately half are from Asia and nearly a third are from Latin America.

Among children, the county hospitalization rate due to asthma is the second highest in the state (384 per 100,000).[23, 27] Hospitalization rates are commonly cited to describe the problem of asthma in the county because they are the only metric available at the ZIP code level. As shown in Figure 1, a broad area beginning along the San Francisco Bay in the northwestern part of the county and stretching eastward across the city of Oakland is commonly noted to include the communities of greatest concern regarding asthma burden. One ZIP code in the neighborhood of West Oakland (94607) has been noted to have a pediatric asthma hospitalization rate seven times the statewide average.[27] This area is perceived to bear a disproportionate burden of air pollution due to the proximity of a large number of interstate highways, heavy industry, and the presence of a major Pacific coast shipping port.

Community needs for asthma surveillance. To complement the development of asthma surveillance techniques, CEHTP initiated a stakeholder input process to learn about the needs and uses for asthma data within Alameda County; in all, representatives from over 20 local organizations became involved. This was an effort on the part of the program staff to incorporate the principles and components of Community-Based Participatory Research.[28] We noted extensive interest in asthma throughout the county from community groups, city and county health agencies, health and environmental advocacy groups, environmental and social justice groups, health care providers, and legislative staffers from a local city council. Using this stakeholder input process, we have been able to characterize some of the current information needs and activities around asthma in Alameda County.

Participants in the stakeholder input process expressed multiple reasons for their interest in asthma, beginning with the direct and personal effect that asthma has on an individual or his/her community. Asthma is also of concern to those working to improve health through prevention or treatment activities. Because of its relationship to components of community well-being—such as housing conditions, health care, and air quality—asthma has gained the attention of the social and environmental justice groups. Finally, government officials with the responsibility to implement programs and develop policies that are responsive to and protective of their constituents have become aware of asthma as a key issue.

Generally, stakeholders use or would like to use asthma information to plan, target, or obtain specific resources such as funding, outreach and education activities, case identification and management, health services, and pollution reduction efforts. Information about asthma is also used for advocacy, decision-making, and evaluation around policies related to public health, the environment, urban planning, and so forth. Finally, some stakeholders use asthma data to initiate discussion and organizing efforts among their communities, as well as to confirm what is suspected or already known at the community level.

Accordingly, stakeholders characterized useful asthma information as information with detail to the community level for multiple asthma indicators. Asthma data that has been analyzed, interpreted, or presented in a social, economic, or environmental context (e.g. analyzed with relation to race/ethnicity, income, accessibility of health care, air quality) is considered useful as well. Asthma data should be easily comparable between communities and with county, state, and national data. Lastly, asthma information should be reliable, available in a timely and regularly updated fashion, and presented in an accessible and comprehensible format.[29]

Materials and Methods

Data sources. The sources and methods for processing of the data for this project, along with discussion of data quality and representativeness, have been described previously.[30] In brief, all Alameda County, California patient records for enrollees younger than 18 years of age in Kaiser Permanente of Northern California (n=135,380) and Medi-Cal (the California Medicaid program) fee-for-service (n=41,409) were assembled and geocoded (with success rates of 94 and 90%, respectively). All together, these data represented approximately 1.7 million person-months of health service utilization. Analysis demonstrated that a large spectrum of socioeconomic strata were represented in the data set, but that the proportion of the population hospitalized for asthma was likely to be under-represented. Although a non-random sample of the county population, this dataset contained information on approximately one of every two child residents (or one in three if calculated in person-months).

Variables. Outcome variables were chosen to represent a range including severe, poorly controlled asthma as well as less severe, well controlled asthma. Previous analysis[30] and clinical reasoning suggested that Emergency Room visits, outpatient visits, symptom medication purchases, and maintenance medication purchases together constituted indicators of such a range of disease.

Emergency Room and outpatient visits were defined as asthma-related if the primary (ICD-9) diagnosis code began with the digits “493.” For records also including a secondary diagnosis code, events were included if the secondary diagnosis was “493” *and* the primary diagnosis was a condition commonly precipitated by an asthma exacerbation, such as “pneumonia” or “respiratory failure.” In order to insure that multiple billing entries arising from a single visit were not counted as multiple events, it was assumed that a single person could only make one outpatient or Emergency Room visit on any given date.

Records of medication purchases were not commonly recorded with an ICD-9 diagnosis. Medications were considered *symptom* (or “rescue”) medications if they were long- or short-acting beta agonists or anticholinergics. *Maintenance* (or “controller”) medications included *inhaled* corticosteroids, methyl xanthines, mast cell stabilizers, and antileukotrienes. Since *oral* corticosteroids are sometimes taken for conditions other than asthma, these medications were excluded in order to maximize the specificity of this indicator.

Disparity estimation. To compare the frequency of health events among communities having different socioeconomic status, we coded each resident address as belonging to a high-poverty ($\geq$ 20% of households) or low-poverty (< 20% of households) census tract. Denominators were the numbers of person-months each person was represented in the census tract category in question; rates were converted to events per person year for presentation. To allow for the magnification of the standard errors of the estimates from some individuals having experiencing multiple events, we calculated confidence intervals using a method adapted from Carriere and Roos.[31]

Density estimation mapping. Data were visualized following the procedure of Rushton and Lolonis.[26] In brief, a grid of regularly-spaced points was calculated for the entire county at 0.5-mile intervals. Overlapping buffers were designated as circles of 0.5-mile radius around each point in the grid (Figure 2). Buffers were included in the analysis if they overlaid enough addresses so that the expected frequency for a given event was four or greater. This criterion resulted in a minimum number of residents ranging from 475 addresses per buffer for the least common event (Emergency Room visits) to 15 addresses per buffer for the most common event (symptom medication purchasing). As a result, between 863 and 1,195 buffers were included in the analyses, depending on the event in question.

Continuous ("raster") surfaces were generated using an inverse distance weighting algorithm that considered the values of the nearest 8 buffer centroids. Surfaces were represented by six color gradations; for consistency, cut-off values between gradations were chosen such that the color representing the highest rates included the 95^{th} percentile rate for the map and above. Colors representing lower rates were chosen using an "equal distance" algorithm ranging from the 95^{th} percentile down to zero.

Monte Carlo simulation. Choice of methods for calculating statistical significance of buffer rates was influenced by the fact that spatial autocorrelation and the overlapping of buffers violated assumptions of independence of measures. Therefore, standard tests of statistical significance assuming independence and normality of distributions could not be used. Monte Carlo simulation was performed by calculating 1,000 sets of events assuming a uniform spatial distribution for the given set of 176,789 addresses and 1.7 million person-months. Buffers were considered statistically significantly different from the county-wide mean if they were below the 2.5^{th} percentile or above the 97.5^{th} percentile for this distribution (the equivalent of a two-tailed significance test with alpha=0.05).

Community review. We reviewed the raster and Monte Carlo simulation images in formal meetings with stakeholders to assess their impressions of communities highlighted by the findings and to understand if the images corresponded with their local experiences. We also superimposed these images on municipal maps, using them to select the census tracts which the areas of concern roughly overlay. In this way, some basic demographic data regarding the highlighted areas could be assembled.

Software. Residence addresses were standardized using ZP4 (Semaphore Corporation, Pismo Beach, CA); they were subsequently geocoded using a custom application written in Java 2, Standard Edition (Sun Microsystems, Santa Clara, CA) and ArcSDE version 9.0 (ESRI, Redlands, CA). Geocoded address coordinates were taken from the first successful match of the following four street centerline datasets (in order): Geographic Data Technology (GDT) Dynamap/2000 version 13 (TeleAtlas, Lebanon, NH), Navigation Technologies NAVSTREETS (NAVTEQ, Chicago, IL), TeleAtlas MultiNet streets (TeleAtlas, Lebenon, NH), and the US Bureau of the Census TIGER 2000 system (Washington, DC). For each street centerline dataset, the first attempt to match an address was made by indexing on the address's ZIP code. Failing that, the phonetic soundex of the address's city was matched against an index of the phonetic soundex of the street centerline's ZIP code post office name.

Custom applications for assigning geocoded addresses to grid buffers were written using ArcObjects version 9.0 (ESRI, Redlands, CA). Monte Carlo simulations were performed by applications written in Java 2, Standard Edition and Transact-SQL and analyzed using SAS version 8.02 (SAS Institute, Cary, NC). Maps were generated using ArcMap version 9.0 (ESRI, Redlands, CA).

Results

Socioeconomic disparities. The rates per 1,000 person-years are shown in Table 1. As expected, residents in high-poverty census tracts had rates of Emergency Room visits due to asthma approximately 66% higher than those in more affluent census tracts. Notably, this relationship was reversed for indicators of relatively well cared-for asthma, with the reverse disparity becoming more pronounced as one considers indicators of higher quality care. For maintenance medications, the purchasing rate is approximately 68% higher among low-poverty census tract residents than among high-poverty census tract residents.

Geographic patterns. Raster surfaces and the geographic distribution of statistically significant ($p < 0.05$) elevations for each event rate are shown in Figures 3 and 4. The distribution of Emergency Room visits due to asthma (Figure 3) is very similar to that of hospitalizations depicted using OSHPD data (Figure 1), with the difference that density estimation allowed for a higher resolution map to be created. Within ZIP codes known to have elevated asthma hospitalization rates, specific areas of concern became visible. Also, additional discrete areas with elevated rates became apparent in several ZIP codes in the far southern and eastern region of the county, although not in comparatively large numbers.

Review of the raster surfaces and Monte Carlo simulations with stakeholders revealed that many of the areas with statistically significant elevations of ER visit rates were recognized by participants as having substantial social and health problems and corresponded with community perceptions of asthma burden. Some elevated areas fit the expected profile of high poverty neighborhoods with majorities of residents of color, while some did not (Table 2).

As predicted by the changing disparities in asthma events represented in Table 1, the geographic distribution of events shifts as one progresses from indicators of severe or poorly controlled asthma to those of milder or well cared for asthma (Figure 4). For the most extreme indicator of thoroughly treated asthma, the purchasing of maintenance medications, the northwestern portions of the county are noticeably devoid of rate elevations; while southern and eastern portions reveal the largest concentration of such elevations.

Discussion

These methods were developed for purposes of ongoing, inexpensive asthma surveillance that would be relevant to organizations (both governmental and community-based) with interests in health, environmental health, and social justice. Our experiences suggest that sophisticated tools for the visualization of asthma disparities in combination with tabular and conventional methods can be instrumental in promoting dialogue among these stakeholders.

Communities of particular concern. We selected some of the areas noted to have statistically significant elevations in rates of ER visits due to asthma, which we considered to correspond to more severe and poorly controlled asthma, for further analysis (Figure 3 and Table 2). From the ZIP code-level analyses and investigations from the county Public Health Department,[32] some of these communities (A-D) had previously been noted as having serious concerns regarding asthma, although not in such a high-resolution manner; these were also neighborhoods that local stakeholders had identified during the course of their work. Others (E-I), however, had not previously been highlighted in this way.

Previous investigators[33] have reported that the burden of asthma falls most heavily on low-income communities and communities of color, and the overall patterns noted in Table 1 are consistent with this pattern. In spite of this finding, the specific areas highlighted by the mapping exercise show striking heterogeneity. Some neighborhoods, such as East and West Oakland, are home to community groups with histories of advocacy work surrounding environmental justice issues. These communities are widely understood to experience a disproportionate exposure to diesel truck traffic, industrial sources of air toxics, waste disposal sites, and the Port of Oakland, a major Pacific Ocean shipping hub. Nearly all are proximal to major interstate highways (the exception is the area in Livermore), although some in particular either include major nexuses of multiple highways (West Oakland and North Oakland) or directly border I-880 (including San Antonio, East Oakland, South Hayward, and South Fremont), which has some of the highest truck traffic in the County. Based on analysis of the census tracts roughly overlying these communities, a wide array of racial/ethnic groups and socioeconomic strata are represented (Table 2).

Enhanced asthma surveillance. Among the advantages of these procedures was increased resolution, which allowed observation of geographic variations that could be directly related to local concerns by stakeholders with knowledge of neighborhood demographics, resource needs, and sources of pollution that had been identified as priorities of interest by the community residents. Through collaboration with local government, non-government, and community-based organizations we were able to assess the utility of these techniques for these purposes. For example, one community representative noted that the Emergency Room raster surface vividly conveyed the fact that many in her community rely heavily on local Emergency Departments as sources of primary care. Other stakeholders were able to use the maps to delineate communities burdened by proximity to multiple interstate roadways while at the same time lacking in health and social services. Similarly, discussion centered on thinly populated areas of the county for which substantive data were not available was minimized.

The maps also enabled us to discover new information regarding the problem of asthma in Alameda County. First, they refined our understanding that, while the “high asthma” areas in the northwestern portions of the county may be due in part to environment and housing conditions in that area, some of the elevations in hospitalization and ER visit rates there are clearly associated with lower usage of primary care (such as outpatient visits and maintenance medication purchases). Primary care utilization has been shown to prevent Emergency Room visits, hospitalizations, and deaths due to asthma.[4-6, 34-38]

Second, the visualization of primary care indicators of asthma revealed areas in the southern and eastern portions with elevated rates that had not previously been discussed as part of the asthma problem in the county. Not only did this provide new information, but it stimulated dialogue regarding what constitutes a public health "problem" in the county. This was because, although asthma may be more endemic to these areas than previously recognized, it appears to be well treated and not associated with some of the morbidity observed elsewhere. On the other hand, it still may constitute a problem from a primary prevention perspective, or to the extent that it indicates that ambient environmental conditions in these locations are adversely affecting the health of residents.

Utility for stakeholders. We felt it important that surveillance data be useful to a broad range of constituents. Although stakeholders at present have had limited opportunities to utilize these data, they have been able to describe several potential uses for this type of health surveillance. The ability to convey disparities in asthma burden at the community level using multiple indicators had been identified by our stakeholder group as particularly valuable. Health education staff were able to prepare the information in an assortment of formats to maximize comprehensibility by lay stakeholders, and they readily incorporated analyses addressing disparities in health access and environmental exposures in their own discussions.

Stakeholders had also prioritized asthma data that could be compared to state and national statistics, but this was an area in which the present analysis fell short. As discussed below (see "Limitations"), the fact that the data are drawn from a non-random sample of Alameda County residents discourages generalization to the county level and subsequent comparison to external "standard" populations.

None of the four population measures of asthma burden (Emergency Room visits, outpatient visits, and symptom and maintenance medication purchases) represents asthma prevalence in a "pure" fashion, since they are all confounded by social factors such as access to care.[39] We found this to be both an advantage and a disadvantage. On one hand, we would have liked to produce a single map with our visualization tool that directly answered the question, "Where is the asthma in Alameda County?" On the other hand, we found that stakeholders expected indicators of asthma prevalence to be inextricably bound up with social structural factors such as access to care or social stressors,[40] and they demonstrated a capacity for using tools that incorporated this fact.

Limitations. The foremost limitation regarding these data is the non-random nature of the sample. In recognition of this limitation, we chose not to calculate neighborhood or county-wide rates of health service use for comparison with known rates calculated from random, national-level samples. Instead we focused on geographic comparisons within the county; although such comparisons may still be subject to sample bias, they are less problematic than comparisons to external rates calculated using differing methods. As noted elsewhere,[30] a high proportion of county residents are represented in the sample, and the geographic distribution of ER visits is tightly correlated with that known for hospitalizations due to asthma. Therefore, our focus on intra-county geographic variations in events rates appears reasonable.

Regarding calculations of statistical significance, our methods do not avoid the "repeated measures" phenomenon. Specifically, given that our selected significance level is 0.05, 5% of all buffer centroids (between 40 and 60 centroids per map) should be expected to have rates “significantly different” from the county average. Therefore, it is important to realize that this technique is not appropriate for testing for the existence of within-county disparities in health service use rates; it can, however, delineate patterns in disparities that are presumed to exist. In light of extensive evidence documenting the existence of social disparities in asthma, the assumption of the existence of such disparities in Alameda County appears valid. Furthermore, statistically significant elevations that appear in clusters, as many of those found in this project do, are less likely to be products of random variation.

Finally, it should be noted that address-geocoded coordinates are only as good as the street centerline products used in their calculation. The primary product that we used (GDT) was updated by the vendor prior to this project, but there remain errors in the coding of geographic coordinates over which we have little control. As we incorporate such technologies into ongoing surveillance efforts, we expect systematic analysis of error rates relative to a sampling of true geopositioned ground coordinates may be useful.

Conclusions. For this project, we sought to develop asthma surveillance techniques using (1) large health service datasets covering a variety of asthma indicators, (2) sophisticated GIS methodologies, and (3) ongoing public stakeholder dialogue. Increases in mapping resolution appear to represent a substantial improvement over the information that has been available historically, and portions of the study area, Alameda County, have been newly identified as being potentially endemic to asthma. We also have found we are able to present a more nuanced picture of asthma in our study area incorporating aspects of both the physical environment (e.g. traffic pollution) and the social environment (e.g. health care access). Although this information is only now being introduced, preliminary discussions suggest that we are able to create and communicate this information in a manner that is responsive to the needs of local government, non-government, and community-based stakeholder needs.

Acknowledgements. This work was supported through a grant from the Centers for Disease Control and Prevention (#U50/CCU922449).

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Table 1. Rates per 1,000 (with 95%-confidence intervals) of asthma-related events by poverty rate of census tract.

Poverty rate in census tract:	Less than 20%	Greater than or equal to 20%
Emergency Room visits	7.0 (6.4 – 7.6)	11.6 (9.9 – 13.2)
Outpatient visits	155 (151 – 159)	141 (132 – 150)
Symptom medication purchases	264 (258 – 270)	215 (203 – 226)
Maintenance medication purchases	158 (153 – 162)	94 (87 – 101)

Table 2. Descriptions of selected Alameda County areas noted to have elevated rates of Emergency Room visits due to asthma based on approximately overlying US census tracts and previously available public health statistics.

Area (reference letter for figure 3)	Predominant (>50%) racial/ethnic group	Poverty rate (%)	Asthma previously a concern?
Neighborhood of North Oakland (A)	African-American	29.6	Yes
Neighborhood of West Oakland (B)	African-American	34.5	Yes
Neighborhood of San Antonio (C)	(diverse)	25.7	Yes
Neighborhood of East Oakland (D)	(diverse)	25.5	Yes
Western portion of city of Castro Valley (E)	White	6.1	No
Neighborhood of South Hayward (F)	(diverse)	7.2	No
Southwestern portion of city of Pleasanton (G)	White	3.3	No
Southeastern portion of city of Livermore (H)	White	5.4	No
Southern portion of city of Fremont (I)	Asian	2.9	No

Figure Legends

Figure 1. Hospitalization rates due to asthma among children aged 0 to 14 years in Alameda County, by zip code tabulation area (ZCTA) of residence, 1998-2000. (Source: California Office of Statewide Healthcare Planning and Development[23]).

Figure 2. Density estimation method for asthma-related health service events. Distance r is set to 0.5 miles (805 m). Rates for grid points (e.g. *A*) are calculated for the populations residing within buffers of radius r. To generate continuous surfaces, non-grid points (e.g. *B*) are assigned inverse-distance weighted averages of their nearest eight neighboring grid point rates.

Figure 3. Raster surface for rates of Emergency Room visits due to asthma among Kaiser Permanente and Medi-Cal fee-for-service enrollees in 2001, Alameda County, California. All indicated points of interest have statistically significantly elevated rates (two-tailed $p<0.05$); descriptions of these points are below.

Figure 4. Raster surfaces and statistically significant elevations ($p < 0.05$) in the spectrum of asthma-related events among Kaiser Permanente and Medi-Cal fee-for-service enrollees in 2001, Alameda County, California. (Asterisks indicate measures not available in dataset).

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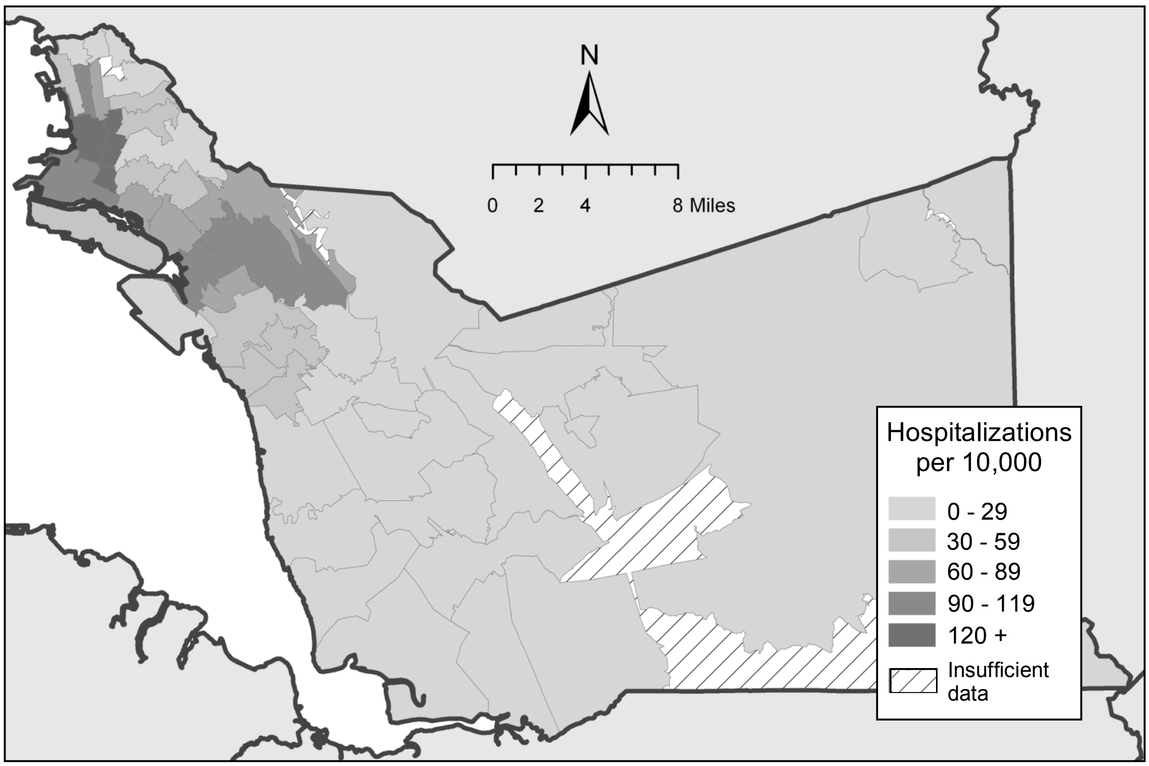
Figures

Figure 1. Hospitalization rates due to asthma among children aged 0 to 14 years in Alameda County, by zip code tabulation area (ZCTA) of residence, 1998-2000. (Source: California Office of Statewide Healthcare Planning and Development[23]).



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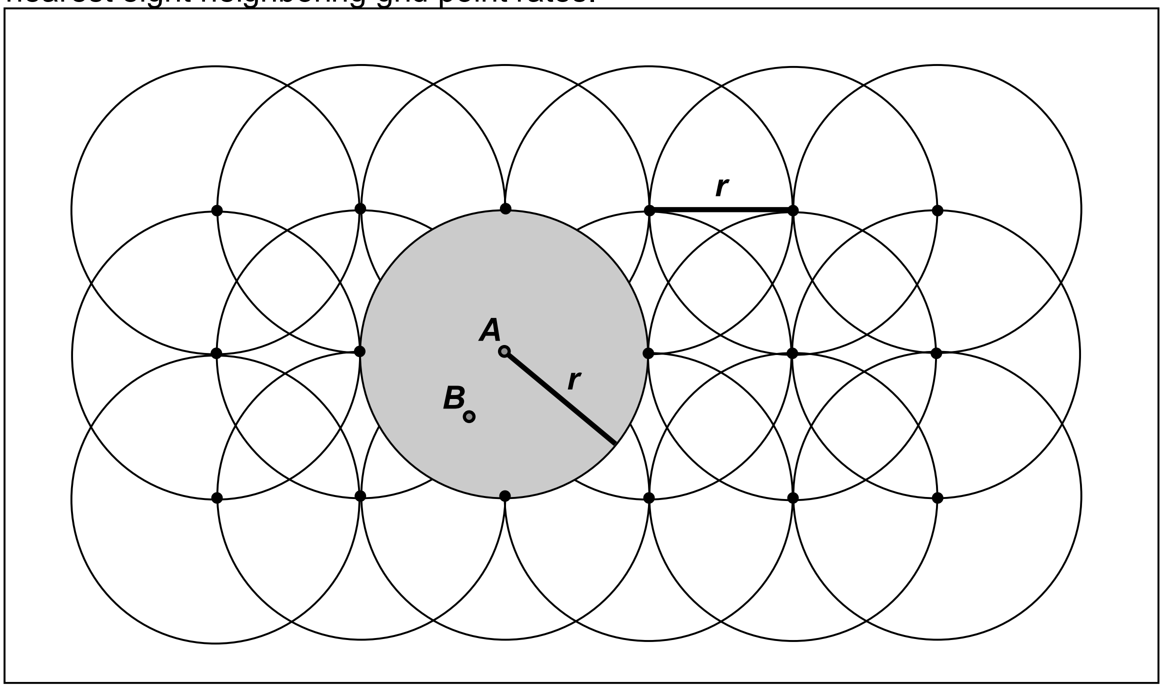

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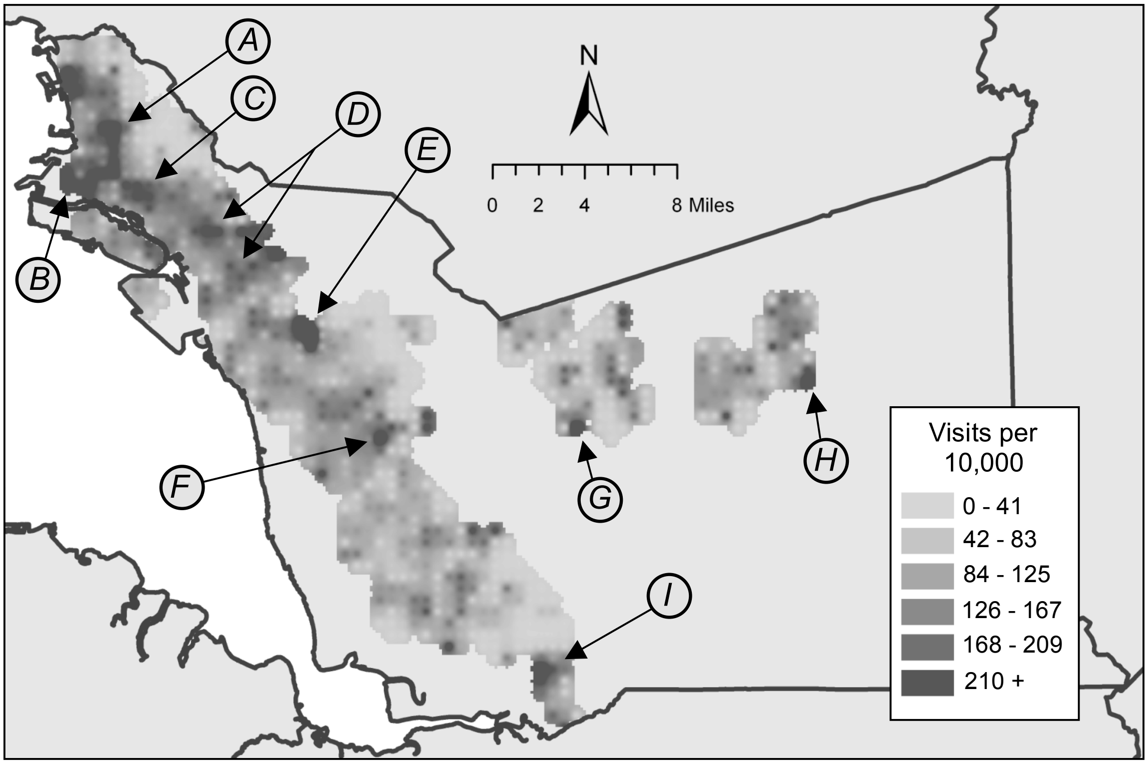

Key: A. Neighborhood of North Oakland; B. Neighborhood of West Oakland; C. Neighborhood of San Antonio; D. Neighborhood of East Oakland; E. Western portion of the city of Casto Valley; F. Neighborhood of South Hayward; G. Southwestern portion of the city of Pleasanton; H. Southeastern portion of the city of Livermore; I. Southern portion of the city of Fremont.

Figure 4. Raster surfaces and statistically significant elevations ($p < 0.05$) in the spectrum of asthma-related events among Kaiser Permanente and Medi-Cal fee-for-service enrollees in 2001, Alameda County, California. (Asterisks indicate measures not available in dataset).