

The Health Status of Residents of the East Coachella Valley

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Introduction

The present report is motivated by the concerns of outspoken residents of the East Coachella Valley (ECV), a desert area located southeast of its more famous neighbor, Palm Springs. Owing to irrigation, the region is an important agricultural valley, yielding a rich bounty of fresh vegetables, citrus, dates and the earliest seasonal harvest of fresh table grapes in the United States.

Through the Building Healthy Communities (BHC) partnership sponsored by The California Endowment, residents point to environmental hazards as threats to their health: foul-smelling fumes, polluted drinking water, inadequate sewage disposal, widespread use of agricultural fertilizers and pesticides in the fields surrounding most communities, and mounds of pesticide-laced trash illegally dumped in the desert. A large trailer park, known locally as Duroville, became the focus of federal intervention aimed at protecting the health of residents from several of these commonplace exposures. Many former residents have been relocated as a result of these concerns. Additionally, a major company, Western Environmental, Inc., has a toxic waste disposal site located near Mecca, a small, unincorporated community in the southern portion of the ECV.

The ECV region is home to thousands of seasonally employed farm laborers who work in the orchards and fields that surround their communities. Much of the population lives in unincorporated communities, such as the town of Mecca, or in trailer parks in the open desert.

Community participants in the BHC point to the prevalence of asthma among young children in the region, and raise the specter of other adverse health outcomes, saying, “We don’t want another Kettleman City,”¹ a reference to the western San Joaquin Valley city where adverse birth outcomes are alleged to be associated with a large toxic waste processing facility located in the hills near that city.

While there has not been a systematic study of population health in the eastern Coachella Valley, a population-based survey in Mecca among farm laborers twelve years ago found an unexpected prevalence of poor health, ranging from widespread chronic health conditions to a lack of access to health care services (Villarejo et al. 2000).

The present report describes findings by physicians and other qualified practitioners on the health of the population residing in the East Coachella Valley. The term “population health” refers to a statistical summary for all residents as whole. It is important to be aware that it is not possible to infer the health status of single individuals, or even a small sub-group of individuals, from such a summary.

¹ Eduardo Guevara, associate director of Promotores Comunitarios del Desierto, a community-based group dedicated to environmental justice in the ECV, *Community View: Coachella Unincorporated*, May 23, 2012.

This overview of the health of residents of the ECV is comprised of several sections: Vital Statistics (Mortality and Live Birth Health), Morbidity (asthma, Reportable Diseases, other non-reportable diseases), followed by Discussion of the findings. Wherever possible, the findings for the ECV population are compared with findings for California as a whole.

Vital Statistics

Vital Statistics describe mortality (deaths) and births in a defined population. Live Birth Health findings are described by Infant Mortality, Low Weight Births, and Very Low Weight Births. The Riverside County Department of Health, in collaboration with public officials and health service providers, has responsibility for compiling the information, providing the data to the California Department of Public Health, and making as much information as possible available to the general public, without compromising individual confidentiality.

Mortality rates

Mortality refers to deaths and is characterized in public records by the age of the decedent, cause of death, year of death and place of residence of the deceased, typically by zip code of the decedent's address. A "mortality rate" is the ratio that characterizes the number of decedents in a given year to the size of the population.

The annual rate of deaths in a population is primarily determined by the ages of persons in the population of interest. For example, if all members of a particular population are old, say, for example, age 65 and older, the mortality rate is generally expected to be quite high because the additional life expectancy of such persons is short compared with their age. In contrast, if the population of a specific geographic area is mostly quite young, as is the case in many areas of the East Coachella Valley, the mortality rate is generally expected to be lower because the additional life expectancy of most residents is long compared with their age.

Thus, the calculated mortality rate, that is simply the number of deaths in a given year divided by the population of the geography of interest, will vary greatly according to the ages of its residents. If calculated, this ratio is called the "Crude Mortality Rate" because it is as much a measure of the ages of the persons in the place of interest as it is a measure of the death rate from all causes of death.

Moreover, if the distribution of ages of residents of a specific geography changes over time, the crude mortality rate will change correspondingly. In many countries, such as Japan and Italy, the annual number of births has declined substantially over time with the result, called "graying of the population," that the population of persons age 65 and older has increased dramatically and the crude mortality rates have soared.

In order to compare mortality rates across different geographies and over different years, demographers and others have agreed on a fixed age distribution to which all rates should refer. This is called the Year 2000 Standard Population (see Appendix I for further details). A mortality rate computed with reference to this fixed age distribution is called an "Age-Adjusted Mortality Rate."

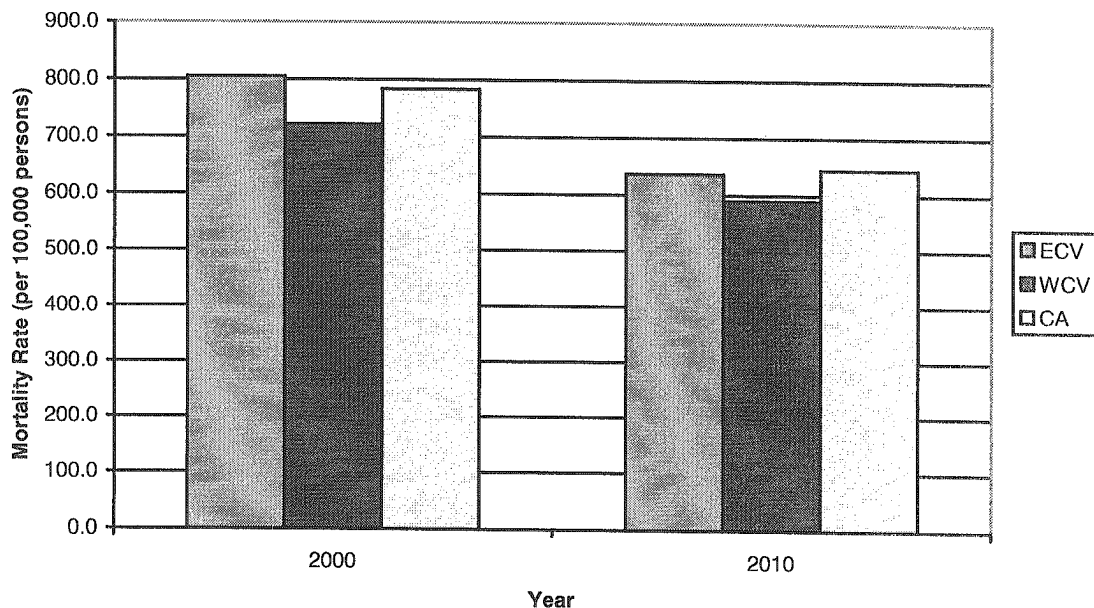
The arithmetic of computing an "Age-Adjusted Mortality Rate" is straightforward. For example, if the proportion of residents age 65 through 74 of a specific geographic area is half of the proportion of the Year 2000 Standard Population, then the number of actual deaths of persons of those ages is multiplied by two to adjust for the difference. Or if the proportion of residents under age 5 is four times greater than the proportion in the Year 2000 Standard Population, then the number of actual deaths of persons under age 5 is divided by four to adjust for the difference.

Age-adjusted mortality rates in the East Coachella Valley

Using data on the reported number of deaths during 2010, by age and zip code, from the California Department of Public Health (California. CDPH. 2010a), and Census 2010 data (U.S. Census Bureau. 2010), the age-adjusted mortality rate in the East Coachella Valley (ECV) in 2010 was 637 deaths per 100,000 residents. This can be compared with the corresponding age-adjusted mortality rates per 100,000 resident during 2010 of 590 for the West Coachella Valley (WCV) and 645 in the California.

Similarly, using data from Census 2000 and CDPH data on deaths, the ECV, WCV and California age-adjusted mortality rates per 100,000 residents during 2000 were 805, 722 and 784, respectively. Both sets of findings are shown in Figure 1.

**Figure 1. Mortality Rate, Age-Adjusted (Year 2000 Standard Population), East Coachella Valley (ECV), West Coachella Valley (WCV) and State of California (CA)
Mortality Rate per 100,000 Persons, 2000 & 2010**



The age-adjusted mortality rate in 2010 for the East Coachella Valley was lower than in the State of California. But the age-adjusted mortality rate in 2010 for the West Coachella Valley was quite a bit lower than either of the rates for the other two regions considered. Also of importance is that the age-adjusted mortality rates of all three regions declined substantially from the corresponding rates in 2000. Moreover, during the ten-year interval, the rate for the East Coachella Valley fell by a larger fraction (-21%) than did the rates for the West Coachella Valley (-18%) or for California (-17%). Finally, in 2000, the age-adjusted mortality rate in the East Coachella Valley was higher than in the state as a whole; the opposite was the case in 2010.

Live birth health

Live birth health is a particularly sensitive measure of exposures to environmental risks owing to the fragile health status of the fetus during gestation as well as posing threats to maternal well-being. There are three measures of live birth health outcomes: Infant Mortality, Low Weight Birth, and Very Low Weight Birth.

The Infant Mortality rate is the ratio, for a specific year and geography, of the number of deaths of persons under the age of 1 year divided by the number of live births. The Low Weight Birth rate is the ratio, for a specific year and geography, of the number of births of babies weighing less than 2,500 grams at birth (about five and one-half pounds) divided by the number of live births. The Very Low Weight Birth rate is the ratio, for a specific year and geography, of the number of births of babies weighing less than 1,500 grams at birth (about three and one-third pounds) divided by the number of live births.

The number of infant deaths in the East Coachella Valley in a given year is quite small, between 9 and 21 during each of the five years, 2006-2010 (California. CDPH. 2010a); it proved necessary to compute an average infant mortality rate for the entire five-year period, 2006-2010. Live birth data for each year and zip code is also available (California. CDPH. 2010b). The computed five-year average Infant Mortality Rate for 2006-2010 in the East Coachella Valley was 5.2 per 1,000 live births (S.D., 1.5).

The corresponding five-year-average Infant Mortality Rate for 2006-2010 in the West Coachella Valley was 5.7 per 1,000 live births (S.D. 2.2). For the State of California the corresponding rate was 5.0 per 1,000 live births (S.D., 0.2).

The small difference in the infant mortality rates between the ECV and California was not statistically significant. In other words, all three rates are identical in terms of the ability of statistical analysis to compare the figures. The national five-year-average infant mortality rate during 2005-2010 was 7.1 per 1,000 live births (CIA).

The number of reported Low Weight births in the East Coachella Valley in a given year also varies considerably from year to year, between 156 and 218 during each of the five years, 2006-2010 (California. CDPH. 2010b). The computed five-year-average Low Weight Birth Rate in the East Coachella Valley was 49.8 per 1,000 live births during 2006-2010 (S.D. 4.6).

The corresponding five-year-average Low Weight Birth Rate for 2006-2010 in the West Coachella Valley was 51.5 per 1,000 live births (S.D. 5.0) while for California the rate was 56.6 per 1,000 live births (S.D. 0.2). Again, the small difference in the Low Weight Birth Rates between the ECV and the WCV was not statistically significant; the two rates are identical in terms of the ability of statistical analysis to compare the figures.

On the other hand, the Low Weight Birth Rate for the East Coachella Valley was significantly lower than the corresponding rate for California (95% C.I.). The rates for the ECV, the WCV and California are all lower than the reported national average of 82 per 1,000 live births during 2009.

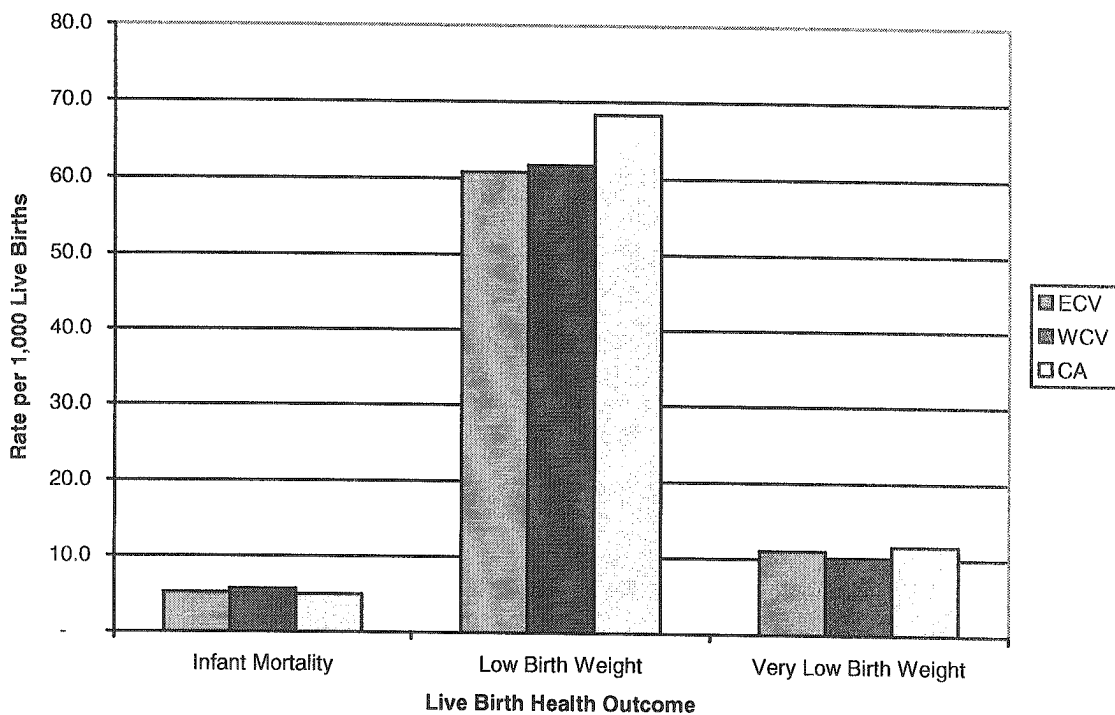
The number of reported Very Low Weight births in the East Coachella Valley in a given year is also small (between 27 and 45 during each of the five years, 2006-2010); it was important to again compute the five-year-average of the Very Low Weight Birth Rate for the period 2006-2010. The computed five-year-average Very Low Weight Birth

Rate in the East Coachella Valley was 11.0 per 1,000 live births during 2006-2010 (S.D., 1.9).

The corresponding five-year-average Very Low Weight Birth Rate for 2006-2010 in the West Coachella Valley was 10.2 per 1,000 live births (S.D. 2.1) while for California the rate was 11.7 per 1,000 live births (S.D. 0.3). Again, the small difference in the low weight birth rates between the ECV, the WCV and California was not statistically significant; the three rates are identical in terms of the ability of statistical analysis to compare the figures. These rates are all lower than the national average of 15 per 1,000 live births.

Figure 2 illustrates the findings of rates per 1,000 live births for all three geographies, and for each of Infant Mortality, Low Weight Births, and Very Low Weight Births.

**Figure 2. Live Birth Health Outcome Rates: Infant Mortality, Low Birth Weight, Very Low Birth Weight, by Region.
Rates per 1,000 Live Births, 5-year Average (2006-2010)**



Morbidity

Morbidity refers to the diseases, illnesses, injuries and disabilities affecting a population, including communicable and non-communicable diseases and illnesses. At a minimum, morbidity data includes information on disease occurrence, or frequency, and distribution patterns in the population of interest. Two measurements of disease frequency are: *incidence* and *prevalence*.

Incidence is the number of *people* contracting a disease during a specific period of time; it is a measurement of the probability of an individual receiving a diagnosis of a specific disease within a given period of time. The calculation for the “incidence rate” is the number of newly diagnosed cases of a disease affecting a population during a specific period of time divided by the number of people at risk for the disease during the same period of time.

Prevalence is the total number of *cases* of disease existing within a population; it is a measurement of the likelihood that an individual has a disease. The calculation for the “prevalence rate” is the number of cases of a disease existing in a population at a given point in time divided by the total population. It is important to note that the term “morbidity rate” can refer to either the incidence or prevalence of a disease within a population.

The initial impetus to track morbidity data stemmed from the need to identify disease outbreaks and to control the spread of infectious, or communicable, diseases. In the late 1800’s and early 1900’s, the U.S. Congress passed a series of legislative measures outlining the authority of the Surgeon General in collaboration with individual states to collect and publish reports on “notifiable” (infectious) diseases (Centers for Disease Control and Prevention 2011). Today, the Center for Disease Control (CDC) maintains the National Notifiable Diseases Surveillance System (NNDSS) that serves as the data consolidation and reporting hub for disease reports from all states and U.S. territories. In California, each county public health agency holds the responsibility for compiling morbidity data from health care provider reports and submitting these reports to the California Department of Public Health.

What information is included in morbidity data?

In addition to the infectious diseases that require mandatory reporting, current morbidity data collection also includes the incidence and prevalence of non-communicable diseases and conditions, such as cancer, diabetes, asthma, pesticide-related illness, and occupational injuries.

There are two primary methods for collecting morbidity data: surveillance systems and systematic national household sample surveys. Disease surveillance is the process of monitoring, maintaining records, and analyzing trends in the spread of disease. Although the “notifiable” or “reportable” disease surveillance system (NNDSS) serves as the principal source of morbidity surveillance data, there are also other sources of surveillance data including: disease registries that track chronic diseases, such as cancer, diabetes, asthma, and congestive heart failure; hospital or clinic records and reports for office visits and hospitalizations or emergency department visits for specific diseases; insurance claim records; and vehicular accident and injury reports.

The second method for collecting morbidity data relies on national population surveys which collect health data from a small representative sample of the population (based on census data) and use the results of these surveys to make estimates for the prevalence of disease within populations. National health surveys also provide additional morbidity data that is not collected through surveillance systems, including health behaviors, chronic disease management, environmental risk factors, and health care practices. The Behavioral Risk Factor Surveillance System Survey² and the National Health Interview Survey (NHIS)³ are two on-going population sample surveys.

Morbidity data based on population surveys is not included in the present report due to the limitations of population sampling for disease estimates within the East Coachella Valley population. For portions of counties, especially regions outside of major population centers, such as the ECV, the relatively small number of cases of a specific disease results in findings that are statistically unreliable. Some of the issues that may contribute to sampling error include: under-representation of difficult to reach populations, sample-size limitations, and low participation rates among community members.

Asthma in the East Coachella Valley

Asthma is a chronic (long-term) lung disease characterized by uncontrolled inflammation and narrowing of the airways within the lungs. Airways are the essential conduits for the flow of air into lung tissue; what we describe as breathing. Substantial narrowing of these passages results in acute respiratory symptoms (wheezing, coughing, shortness of breath, chest pain). Asthma prevalence is associated with the following factors:

- An inherited tendency to develop allergies, called atopy;
- Parents who have asthma;
- The occurrence of some types of respiratory infections during childhood;
- Contact with specific airborne allergens, or exposure to some types of viral infections during infancy or early childhood.

Among children of parents who have asthma, the disease can be triggered by exposure to airborne irritants, such as tobacco smoke. Attacks of asthma can be mild or severe, even life-threatening. Asthma has no known cure but can be managed under the care of a physician and with additional help from local public health practitioners.

Recent research has also demonstrated a strong association between airborne cockroach feces and the mechanism triggering an acute asthma attack (Arruda et al. 2001). It is possible that other particulate matter associated with exposure to cockroaches may be implicated as well.

Asthma is not a reportable disease in California. Physicians are not required to report individual diagnosed cases of the disease to public health authorities. Also limiting efforts to determine the prevalence of the disease in the ECV population is the fact that those living with asthma can choose to seek treatment outside of the U.S., which is the preference of some Spanish-speaking residents of California's southern border counties

² Behavioral Risk Factor Surveillance System (BRFSS) <http://www.cdc.gov/brfss/index.htm>

³ National Health Interview Survey (NHIS) <http://www.cdc.gov/nchs/nhis.htm>

(Villarejo et al. 2000). Knowledge about the regional prevalence of the disease is only available from Emergency Room and hospitalization reports.

The California Department of Public Health makes a substantial effort to gather individual case reports of Emergency Room admissions and hospitalization records of persons who have been diagnosed with asthma by a medical professional. Obviously, persons living with asthma who are treated in Emergency Rooms or are hospitalized represent only the most serious cases of the disease. These records include the age of such persons and their residence address. The data collected in this way are sufficient to yield a profile of the prevalence of the disease within a specific geographic area, and by the age of the patients. However, caution is essential in trying to interpret these data because some individuals afflicted with asthma are known to require two or more Emergency Room, and/or hospitalizations, in a given year. Thus, these data must be regarded as referring to the number of such *incidents*, and not to the actual number of *persons*, which is clearly smaller.

The data for 2009 indicates the age-adjusted incidence rate of Emergency Room visits or hospitalizations attributed to asthma among all residents of the East Coachella Valley was substantially lower than the corresponding rates in California as a whole or, separately, in the West Coachella Valley (California. Environmental Health Tracking Program. 2012). Among East Coachella Valley residents, during 2009, the age-adjusted incidence of Emergency Room visits or hospitalizations associated with medically diagnosed asthma was 32.6 cases per 10,000 persons. This can be compared with the 2009 California statewide age-adjusted incidence rate of 48.0 asthma cases per 10,000 persons. Among West Coachella Valley residents, during 2009, the age-adjusted incidence rate was 43.7 per 10,000 persons. These findings are shown in Figure 3.

Asthma prevalence among children in the East Coachella Valley

The prevalence of serious asthma cases among children ages 0-17 years in California is substantially greater than among adults. This is also true for the East Coachella Valley. Among East Coachella Valley child residents, during 2009, the age-adjusted incidence of Emergency Room visits or hospitalizations associated with medically diagnosed asthma was 57.7 cases per 10,000 children. This can be compared with the 2009 California statewide age-adjusted incidence rate among children of 62.9 asthma cases per 10,000 children. Among West Coachella Valley children, during 2009, the age-adjusted incidence rate was 72.2 per 10,000 children. These findings are shown in Figure 4.

Figure 3. Asthma case Emergency Room visits or Hospitalizations, East Coachella Valley vs. West Coachella Valley and California, Incidence per 10,000 residents, Age-adjusted, 2009

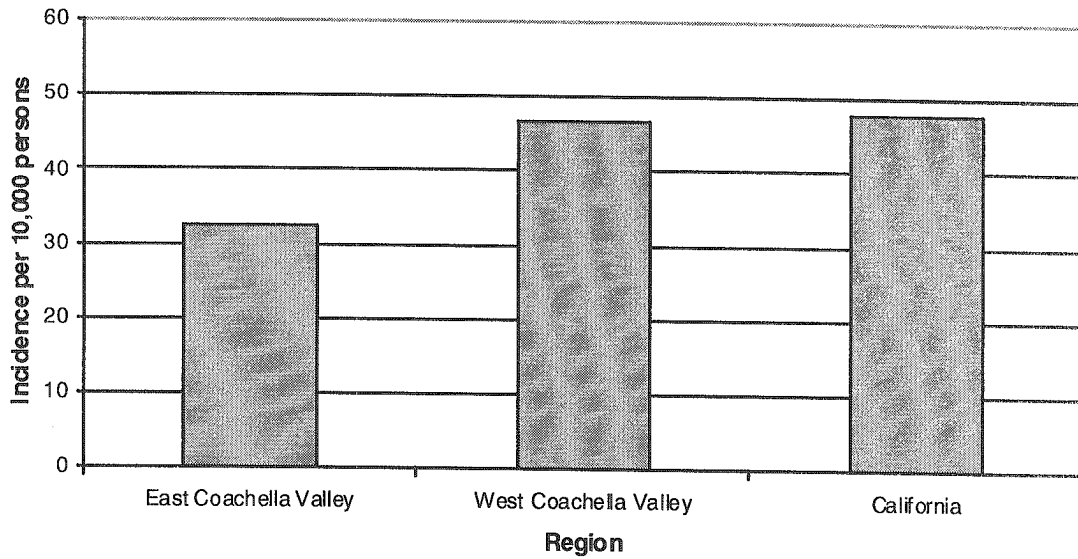
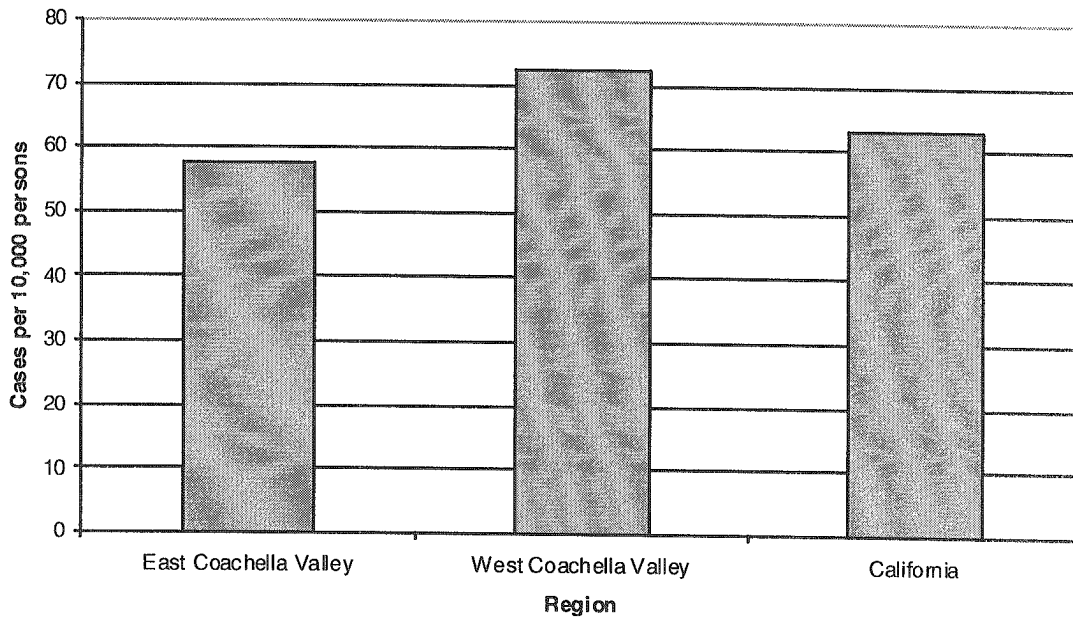


Figure 4. Asthma case Emergency Room visits or Hospitalizations Among Children, East Coachella Valley vs. West Coachella Valley and California, Incidence per 10,000 residents Ages 0-17 years, Age-adjusted, 2009



Notifiable disease reports for Riverside County

As of October 2011, Under Title 17 of the California Code of Regulations, 81 diseases or conditions require mandatory reporting by health care providers to local health authorities (Regulations 2011). The California Department of Public Health (CDPH) provides disease summary reports for selected diseases. Currently the CDPH reports include data for 34 diseases.⁴ These disease reports include incidence counts and rates for selected diseases in California for the years ranging from 1994 to 2010; however, the specific diseases selected for summary reports vary from year to year. Therefore, data is not available for all diseases for each year. Of the 34 diseases summarized in reports, ten diseases had a sufficient number of cases for statistical comparison on a county-wide basis (see Table I).⁵

For most diseases, the yearly county-level summary reports include the number of cases (incidence counts) and the rate per 100,000 people. The reports also include case and rate data at the statewide level by race/ethnicity, age, and month of estimated disease onset.⁶ The state and counties suppress disease data at the zip-code level to protect patient privacy. Therefore, data for the five zip codes of the ECV is not available.

Moreover, because the great majority of cases of the ten diseases with at least 100 cases county-wide for least one year likely occurred in the Riverside Metropolitan area, it is not possible to infer the prevalence of these diseases for a sub-region having a relatively small population. The main point is to protect the privacy of such persons. Thus, data regarding Notifiable Disease prevalence in the ECV is not available.

Table I. Notifiable Diseases with >100 Cases for at least one year during 2000-2010 in Riverside County
Campylobacteriosis
Salmonellosis
Chlamydia
Gonorrhea
Primary and Secondary Syphilis
Latent Unknown Duration/Late/Late Latent Syphilis
Auto Immune Deficiency Syndrome (AIDS)
Hepatitis A
Hepatitis B
Human immunodeficiency virus (HIV)
Viral Meningitis
Pertussis
Sources: (California Department of Public Health 2011) (California Department of Public Health 2003) (California Department of Public Health 2011) (Riverside County Department of Public Health 2010)

⁴ This reflects the data report availability as of June 2012.

⁵ This is based on the minimum threshold of 100 cases required for a 95% confidence interval.

⁶ Reports for HIV/AIDS data present the cumulative total cases, including cases living and deceased.

Non-communicable disease and illness data for Riverside County

Data collection regarding non-communicable diseases and illnesses including, chronic diseases, such as cancer, diabetes, chronic respiratory diseases, and cardiovascular diseases is not federally mandated as it is for the “notifiable” diseases. However, several states, including California, do mandate reporting for cancer to a statewide cancer registry, such as the California Cancer Registry (CCR).⁷ The California Cancer Registry provides cancer morbidity data to Cancer-Rates.Info.com, a cancer database tool that allows the user to create state and county level reports for cancer in selected states. Table II illustrates Riverside county-wide cancer morbidity data generated through queries using the Cancer-Rates.info.com website (California Cancer Registry 2012).

Table II. 2009 Invasive Cancer Incidence Rates among Sub-Populations in Riverside County, California					
Population	Population at Risk	Total Cases	Crude Rate	Age-Adjusted Rate	Statewide Age-Adjusted Rate
Riverside County - all populations	2125440	8452	397.66	419.89	428.09
Riverside County – Males	1063331	4477	421.04	492.63	483.94
Riverside County - Females	1062109	3975	374.26	367.7	390.91
Riverside County - Hispanics	950103	1672	175.98	316.61	334.3
Riverside County - Whites (non-Hispanics)	896603	5763	642.76	459.89	471.83

Note: All rates are per 100,000. Rates are age-adjusted to the 2000 U.S. Standard Million Population. Data accessed June 15, 2012. Based on October 2011 Quarterly Extract (Released October 27, 2011). Veterans Health Administration hospitals did not report cancer cases to the California Cancer Registry (CCR) in 2005-2009. Therefore, case counts and incidence rates for adult males in 2005-2009 are underestimated and should be interpreted with caution (see <http://www.ccrca.org/VAtchnotes.shtml>).

Source: California Cancer Registry. Cancer Incidence/Mortality Rates in California. (California Cancer Registry 2012)

Morbidity data reporting for other chronic diseases and illnesses, such as asthma and diabetes, is not federally mandated at this point. Therefore, the morbidity data collection for these diseases relies on a variety of sources, including hospital discharge data and emergency room visits, physician records, clinic records, health insurance company databases, school records, and federal agencies serving specific populations.

The Office of Statewide Planning and Development compiles discharge data from hospitals through the state of California. Hospital discharge data may provide an incomplete or inaccurate representation of the morbidity within a community due to a variety of issues including, privacy concerns, variability in data management within the institution, access to health care, facility capacity, and lack of defined population to serve as basis for statistical analysis.

⁷See website: <http://www.ccrca.org/index.shtml>.

Pesticide-related illnesses and injuries

The Coachella Valley is an important agricultural region within California. Applications of pesticides have been a standard farm production practice in the valley for many decades. For this reason, the final area of focus for the present report is morbidity data on pesticide-related illnesses and injuries.

The primary statewide surveillance system for pesticide illness is the California Department of Pesticide Regulation's Pesticide Illness Surveillance Program (PISP). The PISP California Pesticide Illness Query (CalPIQ) system provides detailed reports by year, agricultural or non-agricultural source, county, pesticide type, incident setting, application site, exposure type, and activity. Additionally, CalPIQ produces summary reports with grouped variables by activity, county, exposure type, incident setting, and year of incident. (See Table III for summary report data for Riverside County as a whole). Data is not available for the ECV alone.

During the 10-year period, 2000-2009, there were an aggregate total of 247 cases reported county-wide, an average of about 25 per year. Of these, 10 were cases requiring hospitalization and 21 involved temporary disability (inability to work for three or more days).

Table III. Riverside County Pesticide Illness Summary Report for 2000-2009	
Total Cases	247
Total Days of Disability	52
Total Cases with Disability	21
Total Days of Hospitalization	43
Total Cases with Hospitalization	10

Source: CalPIQ-California Pesticide Illness Query from DPR's Pesticide Illness Surveillance Program (PISP) database (California Department of Pesticide Regulation 2012).

Discussion

The present report summarizes health status findings by physicians and public health officers for residents of the East Coachella Valley (ECV). Importantly, as measured by Vital Statistics (deaths and live births), the health of the ECV population compared favorably with that of the entire California population, and ECV Low Weight Birth health was better than in the state as a whole.

It might be expected that the ECV population would be characterized as having poor health because the region has a high proportion of people in poverty and a substantial majority of Latinos, many of whom lack health insurance or regular access to health care services. No doubt there are more than a few residents who are in poor health. On the other hand, the median age of the ECV population is substantially lower than that of California which implies a lower prevalence of serious chronic (long-term) disease in the population. And the large proportion of recent Latino immigrants is an important factor in the more favorable birth outcomes, despite low socio-economic status, probably reflecting the so-called “Hispanic paradox.”⁸

A major concern of ECV residents is the occurrence of asthma in the population, particularly among young children. However, reports from emergency rooms in the region, as well as hospital discharge data, finds the ECV asthma incidence rate per 10,000 residents is substantially lower than in California as a whole (32.6 per 10,000 persons vs. 48.0 per 10,000 persons, respectively). Among children ages 0-17 years, the ECV incidence rate is also lower than statewide, but the difference is smaller (57.7 cases per 10,000 persons vs. 62.9 per 10,000 persons, respectively). Among very young children ages 0-5 years, the number of ECV cases is too small to separately report without violating confidentiality guidelines.

This finding of a lower incidence rate of asthma disease in the ECV population than is found statewide does not alter the concern of those ECV residents whose family members are afflicted with the disease. Rather, it simply suggests that there is no greater danger of becoming ill with asthma by residing in the ECV than if one lived in most other places in the state.

The prevalence of communicable disease (Notifiable Diseases) and cancer in the ECV could not be determined in the present study. This is an additional consequence of public laws that are intended to protect patient privacy and confidentiality. However, county-wide summary data is available but those findings are likely dominated by health conditions prevailing in the major population areas of the county.

Similarly, pesticide poisoning case summary reports are only available on a county-wide basis, precluding analysis for the ECV region. It is important to note that some cases of pesticide injury or illness may go unreported, particularly if hired farm workers are involved, because the condition might be attributed to other types of outdoor exposures, or to pre-existing health conditions, such as allergies.

There is a significant limitation of the data. An unknown number of ECV residents go to Mexicali or other communities in Mexico to seek health care services. Presumably, reports concerning their health conditions are not recorded in U.S. public health data reporting systems. Mexico is seen by some residents as a much more

⁸ The Hispanic paradox refers to the well-documented public health finding that immigrant Hispanic women have more favorable birth outcomes than U.S.-born white women.

desirable place to seek treatment for adverse health conditions. For Mexican nationals who prefer to speak their native language, there are sometimes problems with U.S. providers who have only limited fluency in Spanish, or none at all. Cultural differences may also be significant. Finally, health care costs are frequently much higher in the U.S. than in Mexico.

Airborne particulate matter and desert winds

An important type of exposure in the interior desert is airborne particulate matter, such as very small (less than 10 micron) dust or sand particles born by desert windstorms. In the ECV, there is also the risk of exposures to other types of contaminants found in such diverse settings as illegal waste dumps or inadequate sewage disposal systems. Whether the burning of tires or fumes from pesticide-laden waste dumped in the desert, the risk of environmental exposures to toxic materials is probably more likely in remote, unincorporated areas than in most urban settings.

It is also known that smog from the Los Angeles basin regularly intrudes into eastern Riverside County, adding to the burden of local-origin pollutants. The effect of such smog on the ECV population has not been studied.

Some of these types of potential airborne particulate hazards are more fully described in Appendix II. However, there is no comprehensive environmental hazard survey for the entire ECV for which it is presently possible to assess the risk to residents, whether nearby or distant. Thus, attention tends to be directed to intentionally toxic sites, such as the Western Environmental facility.

The Kettleman City analogy

Some advocates suggest that the ECV faces the kind of risks to child health that are the subject of a multi-year conflict between outspoken residents of Kettleman City, a small west San Joaquin Valley community, and a neighboring toxic waste site located in the hills west of town. The unusual prevalence of birth defects among children born to women residing in that community during 2008 is the source of this dispute. Like much of the ECV, Kettleman City is populated mostly by Latinos, a great many of whom are farm laborers, and it is a poor community.

The present authors think that it is quite important that such references in discourse about the ECV rely on the most accurate evidence currently available. In the most recent findings, based on careful research conducted by suitably qualified medical experts, the California Department of Public Health suggest the prevalence rate of serious adverse health outcomes, such as major birth defects, is likely to be no greater in Kettleman City than in the surrounding regions of the Central Valley based on the statistical reliability of the number of reported cases (California. Department of Public Health. 2012).

If the on-going investigation by qualified medical experts continues to support this interpretation of the risks to health in Kettleman City, then it would appear to the present authors to be unwise to refer again to this dispute in future discourse concerning the ECV. Rather, a focus on environmental hazards in the ECV would likely be more productive.

Further research

The well-known association of higher asthma prevalence among residents of sub-standard housing might have a previously unrecognized cause. Cockroach feces were found to be a particularly powerful trigger of the asthma health condition (Arruda et al. 2001). This suggests that it would be important to measure exposures to this irritant. Particles of this irritant can become airborne when attached to small pieces of dust or other materials normally found in home settings.

It has been shown that farm labor housing has a higher prevalence of sub-standard conditions than in the general population (Villarejo and Schenker. 2007). The prevalence of inadequate housing among hired farm worker dwellings in Mecca during a 1999 health survey was demonstrated to be especially high. More recently, the nearby community of Duroville was also identified as having a very high prevalence of sub-standard dwellings and, for this reason, is presently being closed owing to Federal court intervention.

Among the further options to be considered for further investigation are the following:

- Continue to pursue zip code level (or an aggregate of the five zip-codes) reportable disease data from Riverside County
- Compile cancer data for East Coachella Valley hospitals from the Office of Statewide Planning and Development hospital discharge reports
- Compile hospital discharge data for asthma and/or diabetes for 2000-2010
- Continue to pursue pesticide illness data from the Riverside County Agricultural Commissioner's Office
- Conduct primary research, including interviews with local health care practitioners regarding data and trends in patient morbidity

References

- Arruda LK, Vailes LD, Ferriani VP, Santos AB, Pomes A, Chapman MD. 2001. "Cockroach allergens and asthma." *J Allergy Clin Immunol* 107(3):419-28 (March).
- California Cancer Registry (2012). "Cancer Incidence/Mortality Rates in California. ." Retrieved June 15, 2012, from <http://www.cancer-rates.info/ca/index.php>.
- California. Code of Regulations, C. C. o. (2011). Sections 2500, 2593, 2641.5-2643.20, and 2800-2812. Reportable Diseases and Conditions. Title 17 United States, California Department of Public Health. **110a**.
- California. Department of Pesticide Regulation, P. I. S. P. D.-P. (2012). " California Pesticide Illness Query (CalPIQ) system report." Retrieved June 14, 2012, from http://apps.cdpr.ca.gov/calpiq/calpiq_input.cfm.
- California. Department of Public Health. "Birth Defects in Kettleman City and Surrounding Areas. 2009-2011 Update," June 19, 2012.
- California. Department of Public Health. 2012. Environmental Health Tracking Program. Cf. http://www.cehtp.org/data/Asthma_ED_allages_byzip_2009.csv. Retrieved July 30, 2012.
- California. Department of Public Health. 2010a. Death Profiles by Zip Code. Annual. "Number of Deaths by Zip Code of Decedents Residence Address, by Sex and Age of the Decedent, and Selected Leading Causes of Death, California, 2010." Cf. <http://www.cdph.ca.gov/data/statistics/Documents/DeathZip2010.xls>
- California. Department of Public Health. 2010b. Birth Profiles by Zip Code. Annual. "California Birth Profiles by Zip Code, 2010. Number of Live Births by Zip Code of Mother's Residence, by Race and Age of Mother, Infant Birth Weight, and Mother's Prenatal Care." Cf. <http://www.cdph.ca.gov/data/statistics/Documents/birthzip2010.xls>
- California. Department of Public Health, C. f. I. D., Division of Communicable Disease Control, Infectious Diseases Branch, Surveillance and Statistics Section. (2011). "Yearly Summary Reports of Selected General Communicable Diseases in California 2001-2010.". Retrieved June 3, 2012, from <http://www.cdph.ca.gov/data/statistics/Pages/CD-YearlyTables.aspx>.
- California. Department of Public Health, C. f. I. D., Division of Communicable Disease Control, Infectious Diseases Branch, Surveillance and Statistics Section. (2011). "Epidemiological Summaries of Selected General Communicable Diseases in California, 2001-2008.". Retrieved June 5, 2012, from <http://www.cdph.ca.gov/data/statistics/Pages/EpiSummariesCDsCA-01-08.aspx>.

California. Department of Public Health, D. o. H. S., Division of Communicable Disease Control, Infectious Diseases Branch, Surveillance and Statistics Section. (2003). "Communicable Diseases in California 1999-2000." Retrieved June 5, 2012, from <http://www.cdph.ca.gov/data/statistics/Pages/CDdata.aspx>.

Riverside County. Department of Public Health (2010). "Communicable Disease Report 2010. ." from <http://www.rivcohealthdata.org/reports/commrpt.htm>.

Riverside County. Department of Public Health, E. a. P. E. B. (2004). "Hospital Discharges for Asthma: 1993-2003.". Retrieved June 14, 2012, from <http://www.rivcohealthdata.org/reports/asthma.htm>.

Riverside County. Department of Public Health, E. a. P. E. B. (2006). "Diabetes Hospitalizations." Retrieved June 14, 2012, from <http://www.rivcohealthdata.org/reports/diabetes.htm>.

United States. Centers for Disease Control and Prevention (2011). "National Notifiable Diseases Surveillance System." Retrieved June 14, 2012, from http://www.cdc.gov/osels/ph_surveillance/nndss/nndsshis.htm.

United States. Census Bureau. 2010. 2010 Census Summary File 1. "Table QT-P1. Age Groups and Sex: 2010." Data for selected Geographies identified as ZCTA 92201, et seq.

Villarejo D and Schenker MB. 2007. *Environmental Health Policy and California's Farm Labor Housing*, Policy paper, John Muir Institute of the Environment, University of California, Davis, May 2007.

Villarejo D, Lighthall D, Williams D III, Souter A, Mines R, Bade B, Samuels S, McCurdy SA. 2000. *Suffering in Silence: A Report on the Health of California's Agricultural Workers*. The California Endowment & California Institute for Rural Studies, Davis, CA, 37 p (November).

Appendix I. Year 2000 Standard Population

The Year 2000 Standard Population is a fixed set of numbers of persons in each of a dozen age groups, based on Census data for the United States. For simplicity, the total number of such persons is arbitrarily set to equal 1,000,000, so that the total number of persons for all age groups is this table. The proportion of persons in each age group is computed as a “weighting factor,” each of which is a number less than 1. If the weighting factor for a specific age group is multiplied by 100, the result is the percent of persons in the Year 2000 Standard Population within that age group. The sum of all weighting factors equals the number 1.

The table below presents the Year 2000 Standard Population used in the present report.

<i>Age</i>	<i>Number of Persons</i>	<i>Weight</i>
All ages	1,000,000	1.000000
Under 1 year	13,818	0.013818
1-4 years	55,317	0.055317
5-14 years	145,565	0.145565
15-24 years	138,646	0.138646
25-34 years	135,573	0.135573
35-44 years	162,613	0.162613
45-54 years	134,834	0.134834
55-64 years	87,247	0.087247
65-74 years	66,037	0.066037
75-84 years	44,842	0.044842
85 years and over	15,508	0.015508

Source: Anderson RN Rosenberg HM. 1998. “Age Standardization of Death Rates: Implementation of the Year 2000 Standard.” *National Vital Statistics Reports*; 47(3): 1-16 (October 7). Cf. Table C, p. 4.

Appendix II. Known health effects of specific airborne materials

Tire fire smoke

In the state of California, about 21 million waste tires are generated yearly. This is a small portion of the total municipal waste stream (one-half of 1%) but their disposal challenges are unique from both a regulatory and health standpoint. As a result of state regulations on the disposal of tires, fees for disposal have increased resulting in tire stockpiles and illegal dumps. These stockpiles present a risk to the environment and public health. Health risks arise specifically from the potential for tire fires.

Even when piled densely there is usually enough air space around tire piles to make them highly combustible. An average tire is produced from about 2.5 gallons of petroleum, making it a good source of heat energy. Shredded or chipped tires, without their steel belts, have an energy content ranging from 14,000 to 15,000 Btu per pound. (Coal has an energy content of 8,000 to 12,000 Btu per pound.)

The high level of heat generated by tire fires makes them difficult to extinguish. Uncontrolled burning of tire piles produces smoke and toxic air pollutants, most notably benzene, carbon monoxide and polycyclic aromatic hydrocarbons (PAH). In addition to the airborne contaminants, intense heat from tire fires generates pyrolytic oil that mixes with extinguishing material and can contaminate surrounding soils, surface waters, and groundwater. The ash from burnt tires can include high levels of heavy metals such as lead, cadmium and zinc.

Contaminants in tire fires

To evaluate the risks to communities from tire fires, potential exposure while the fire is burning and potential exposure after the fire is out must both be considered. Whether a health hazard exists is based on comparing emissions estimates with established safe levels for those compounds. Based upon available information, the following chemical hazards are of concern.

While the tires are still burning, smoke plumes may contain hazardous substances that should not be inhaled or allowed to contact the skin. The two main substances from burning tires for which excessive exposure risk exists are believed to be polycyclic aromatic hydrocarbons (PAH) and carbon monoxide.

Polycyclic aromatic hydrocarbons are a class of compounds of various arrangements and substitutions of multiple benzene rings. PAHs result mainly from the incomplete combustion or high-temperature treatment of coal-derived materials. Benzene compounds may be produced as part of the thermal breakdown and reformation of molecules in the cooling process.¹

Carbon monoxide (CO) is an odorless, colorless, and tasteless gas usually resulting from incomplete combustion.

Other substances that pose a lesser exposure risk include metals and solvent vapors. Airborne exposure to these substances in the plume may pose a health hazard. Organic compounds of potential concern include toluene, xylene, ethyl benzene, and styrene.

Health effects of exposure to tire fires

There are no published exposure limits to PAHs. However, epidemiological studies of the cancer mortality rates among workers that have had high PAH exposure show an association with increased mortality from lung cancer.

When inhaled, carbon monoxide combines with hemoglobin to form carboxyhemoglobin, which interferes with the oxygen-carrying capacity of blood, resulting in a state of tissue hypoxia. Typical signs and symptoms of acute CO poisoning are headache, dizziness, drowsiness, nausea, vomiting, collapse, coma, and death.

Benzene may cause adverse health effects through inhalation, ingestion, or dermal contact. Acute exposure symptoms include dizziness, euphoria, giddiness, headache, nausea, weakness, drowsiness, respiratory irritation, pulmonary edema, and pneumonia. Benzene can also cause irritation to the skin, eyes, and mucous membranes. Aromatic hydrocarbons typically cause central nervous system depression or other effects as well as hepatic, renal, or bone marrow disorders. These effects are dependent on the compound.

The presence of heavy metals in the ash from tire fires may also present a health hazard concern. High concentrations of zinc, lead, or arsenic have been found in sample analysis from various fires. Dermal or skin contact with contaminated materials should be avoided. The metals act as primary irritants by removing the surface film, disturbing the water-holding quality of the cells, and injuring the membrane structure of the epidermal cells.

Some smoke constituents (e.g. irritants and small particles) are known to trigger asthma attacks in people with preexisting asthma. Stanislaus County data on clinic visits and phone calls seems to indicate that asthmatics did experience exacerbation of symptoms. People who have been exposed to tire fire smoke, for example at the Westley tire fire, have reported symptoms that would result from exposure to irritants. ⁱⁱ

Landfill fire smoke

Fires occur at landfill sites across the United States and are an ongoing problem that has existed for decades. Landfill fires threaten the environment and human health through emission of toxic pollutants into the air, water, and soil. The degree of risk depends on the contents buried in the landfill, the geography of the landfill, and the nature of the fire. It can be difficult to detect and extinguish landfill fires because they often smolder for long periods below the surface of the landfill before they are discovered. Smoke from landfill fires generally contains particulate matter (the products of incomplete combustion of the fuel source), toxic smoke and gases. Included in the toxins produced in landfill fires may be dioxins. Fires at landfills and unauthorized burning of residential waste are considered the largest sources of dioxin emissions in the United States. Dioxins are a group of chemical compounds that are formed as a result of combustion processes and also are naturally occurring and ubiquitous.

Health impacts of landfill fires

Even without the existence of these dangerous chemical compounds, smoke can aggravate existing respiratory conditions.

Underground fires can result in carbon monoxide (CO) levels in excess of 50,000 ppm—the Occupational Safety and Health Administration (OSHA) permissible exposure limit for CO is 50 ppm. Carbon monoxide is harmful when breathed because it displaces

oxygen in the blood starving the heart, brain, and other vital organs of oxygen and in high enough exposures can cause organ damage or death.ⁱⁱⁱ

Dioxins have been characterized by EPA as likely human carcinogens that are anticipated to increase the risk of cancer at background levels of exposure. However, exposure to high levels has been linked to cancer, liver damage, skin rashes, and reproductive and developmental disorders.^{iv}

Sewage sludge

Biosolids are the by-product of wastewater treatment, created by processing human waste at about 250 treatment plants and collection systems throughout California. The terms biosolids and sewage sludge are often used interchangeably. The legal term for biosolids by law is sludge.^v According to the California Association of Sanitation Agencies (CASA), California generates 750,000 dry tons of sludge solids every year, most of which are considered *Class B biosolids*. Class B biosolids are sewage sludge that has undergone treatment to reduce pathogen concentrations, including aerobic and anaerobic digestion, air drying, composting, and lime stabilization. According to the U. S. Environmental Protection Agency (EPA), Class B biosolids may still contain pathogens in sufficient quantity to warrant restricted public access and special precautions for exposed workers.^{vi}

Of the total 750,000 dry tons of treated sludge:

- 54 percent are land applied.
- 16 percent are composted.
- 12 percent are used as alternative daily cover at landfills.
- 6 percent are disposed of in landfills.
- 4 percent are surface disposed.
- 8 percent are incinerated or stored.

Contaminants in Sewage Sludge

A wide variety of undesirable chemicals may be found in sludge which could have adverse effects on the environment and human health.^{vii} Sewage sludge contains a high concentration of wastes. 332 organic compounds with known or suspected toxic effects have been detected in sewage sludges, 42 of them regularly.^{viii} The physical-chemical processes involved in the treatment of sewage sludge tend to concentrate heavy metals and poorly biodegradable trace organic compounds as well as potentially pathogenic organisms (viruses, bacteria etc) present in waste waters.

Open air application or storage of sewage sludge can lead to the transport of pathogens through bioaerosols downwind of sludge storage or spreading sites, through contamination of ground water, drinking water wells, stock ponds and surface waters or through food that has come into contact with sludge. Pathogens can be transported to humans who walk through sludge. Wild animals, farm animals, birds, rodents and pets may become infected by or transmit sludge pathogens. A recent study from the University of Arizona shows that the risk of windborne pathogens is significant within a 10 km radius of a sludge spread field.^{ix}

Open field storage of sludge and sludge spreading near wells and surface water increase the risk that sewage sludge pathogens will be transported to workers, farmers

and neighbors, and increases the environmental risks of this waste disposal practice. The case against open storage of sewage byproducts does not stop with the issues posed by pathogens; other health risks are associated with the elevation of heavy metals in soils and foods, the release of mercury into the atmosphere from sludge and the presence of priority pollutants in the sludge. "The priority pollutants are a subset of "toxic pollutants" as defined in the Clean Water Act (USA). These 126 pollutants were assigned a high priority for development of water quality criteria and effluent limitation guidelines because they are frequently found in wastewater."^x

Acceptable levels of contaminants in sewage sludge set by the Environmental Protection Agency (EPA) were based on historical data for indicator organisms in water (E. coli and Salmonella) and a national survey that tested for 420 of the approximately 60,000 industrial pollutants potentially present in sludge. Concerns were raised about the long-term effects of sewage sludge on public health and the environment by EPA scientists.^{xi}

Health effects of exposure to sewage sludge

Symptoms of exposure to sewage or sewage sludge include severe irritation to mucous membranes followed by respiratory infections, similar to infections after exposure to irritant gases. In a study involving fifty randomly selected workers in a sewage treatment plant in Toronto, Canada, symptoms of exposure to sewage sludge were assessed.

The research showed that many workers reported "influenza-like" symptoms, cough, sputum production, wheezing, sore throat and skin complaints. The workers tended to have somewhat reduced lung function. Workers in the area of the plant where boiled sewage sludge was dried frequently reported an intermittent, acute illness characterized by cough, fever and sore throat. Workers in the area of the plant where the dried sludge was incinerated tended to have reduced lung function.^{xiii}

Organic gases

Sewer gas

Sewer gas is another irritant that can be present when sewage is not treated properly. This gas is generally hydrogen sulfide, which smells similar to rotten eggs. Sewer gas is colorless, but has a strong odor. It is a natural byproduct of the breakdown of waste material. It may be present as the result of a malfunctioning sewer venting system. Sewer drains by dry traps sometimes allow sewer gas to enter a home or other enclosed space.

Health impacts of sewer gas

Hydrogen sulfide can affect the body if it is inhaled or comes in contact with the eyes, skin, nose or throat. Inhalation may cause headache, dizziness and upset stomach. Exposure to higher concentrations of hydrogen sulfide may result in loss of consciousness and death.

Smelling sewer gas at low concentrations is not deadly, but can cause eye and throat irritation, coughing and trouble breathing. Long-term effects of inhaling low concentrations of hydrogen sulfide gas include fatigue, loss of appetite and headache. Prolonged exposure to low or moderate levels of hydrogen sulfide may result in mild to

severe symptoms: skin may itch, burn or have red and inflamed areas. According to the Department of Health in New York, workers exposed to hydrogen sulfide over time experienced impaired lung function, slower reaction times, poor balance and loss of short-term memory. Other symptoms included inflamed eye membranes, coughing and nasal problems, and headaches.^{xiii}

A 2001 study noted an increase in asthma-related hospital visits among children following days when hydrogen sulfide levels were above 30 ppb.^{xiv} In open areas where raw sewage is present, the unpleasant smell is likely the worst effect, assuming there is no long-term exposure. Particles of raw sewage are able to become airborne, however, and inhalation of these particles causes adverse health effects such as gastrointestinal discomfort, diarrhea, nausea and vomiting. Raw sewage poses the biggest threat to public health when it enters the water supply, where it is diluted and spread much wider than where it originated. While boiling water before consuming it minimizes the risk of waterborne illness, there is a high risk of potentially deadly diseases such as cholera and dysentery from drinking water contaminated with raw sewage.

Landfill gas

Landfill gas is generated during the bacterial decomposition of organic material stored in solid waste landfills. A number of factors influence the quantity of gas that a landfill generates and the constituents of that gas including the age, type, moisture content and temperature of the waste.^{xv} Landfill gas is primarily made up of methane and carbon dioxide. However, landfill gas also commonly contains hydrogen sulfide, dimethyl sulfide, mercaptans, ammonia and other non-methane organic components.

Health impacts of landfill gas

Exposures to elevated levels of ammonia and hydrogen sulfide in air over a short term can cause coughing, irritation of the eyes, nose, and throat, headache, nausea, and breathing difficulties. These effects usually go away once the exposure is stopped.

Studies have been conducted in communities near landfills and waste lagoons to evaluate health effects associated with longer term exposure to landfill gases. These studies reported health complaints which coincided with periods of elevated levels of hydrogen sulfide and landfill odors. Complaints included eye, throat and lung irritation, nausea, headache, nasal blockage, sleeping difficulties, weight loss, chest pain, and aggravation of asthma. Although other chemicals may have been present in the air, many of these effects are consistent with exposure to hydrogen sulfide.^{xvi}

The effects of odors on day-to-day life can be more lasting than the effects of short term exposures to gases. "Families living close to a landfill in Connecticut described frequent odor events as overwhelmingly disruptive. One family reported being awakened during predawn hours by a flood of nauseating air that persisted for 2 or more hours. The loss of sleep and the frustration from the frequent odor events greatly added to the level of stress in the family's life. Although landfill odors may not be associated with long-term adverse health effects or illness for most people, the added disruption and stress of day-to-day activities can greatly impact quality of life."^{xvii}

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- ⁱ LEA Advisory #46--November 6, 1997, *Evaluation of Employee Health Risk from Open Tire Burning, Site-Specific Health and Safety Report*
- ⁱⁱ U.S. EPA (October 1997) Air Emissions from Scrap Tire Combustion.
- ⁱⁱⁱ OSHA Fact Sheet, Carbon Monoxide Poisoning, U.S. Department of Labor, Occupational Safety and Health Administration, 2002. http://www.osha.gov/OshDoc/data_General_Facts/carbonmonoxide-factsheet.pdf
- ^{iv} Questions and Answers About Dioxins, Environmental Protection Agency, July 2000, p. 6. <http://www.epa.gov/ncea/pdfs/dioxin/dioxin%20questions%20and%20answers.pdf>.
- ^v <http://deadlydeceit.com/RCRA.html>
- ^{vi} <http://www.calrecycle.ca.gov/organics/biosolids/>
- ^{vii} Langenkamp, H. & L. Marmo (Eds.) (2000): *Workshop on Problems Around Sewage Sludge*, 18-19 November 1999 (NO) Italy Proceedings.-European Commissions Joint Research Center, EUR 19657 EN, 242.
- ^{viii} Drescher-Kaden, U., Brüggemann R., Matthes B. & M. Matthies (1992): Contents of organic pollutants in German sewage sludges.-in: Hall, J. E., Sauerbeck, D. R. & P. L'Hermite (1992), 14 - 34.
- ^{ix} Dowd SF, Gerba CP, Pepper IL, Pillai SD. 2000. *Ecological risk assessment: Bioaerosol transport modeling and risk assessment in relation to biosolid placement.* J Environ Qual 2000;29:343-8.
- ^x Corrosion Doctors Glossary, <http://corrosion-doctors.org/NaturalWaters/Pollutants.htm>, accessed 10/23/12.
- ^{xi} Lewis, David L.; Shepherd, Samuel; Gattie, David K.; Sanchez, Susan; Novak, Marc. 2001. *Enhanced Susceptibility To Infection From Exposure To Gases Emitted By Sewage Sludge: A Case Study* Proceedings of the Water Environment Federation, Innovative Uses of Biosolids and Biosolids Management 2001 , pp. 392-399(8)
- ^{xii} James R. Nethercott & D. Linn Holness . (1988) *Health Status of a Group of Sewage Treatment Workers in Toronto, Canada*, pages 346-350 Am Ind Hyg Assoc J. 1988 Jul;49(7):346-50.
- ^{xiii} Agency for Toxic Substances and Disease Registry, 2006. *Toxic Substances Portal – Hydrogen Sulfide.* <http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=388&tid=67>
- ^{xiv} Campagna D, Kathman SJ, Pierson R, Inserra SG, Phifer BL, Middleton DC, Zarus GM, White MC. 2004. *Ambient hydrogen sulfide, total reduced sulfur, and hospital visits for respiratory diseases in northeast Nebraska, 1998-2000.* Expo Anal Environ Epidemiol. 2004. Mar;14(2):180-7
- ^{xv} Environmental Protection Agency. Landfill Methane Outreach Program, Basic Information. <http://www.epa.gov/lmop/basic-info/index.html#a02>
- ^{xvi} New York Department of Health, http://www.health.ny.gov/environmental/outdoors/air/landfill_gas.htm
- ^{xvii} Agency for Toxic Substances and Disease Registry, 2001. *Landfill Gas Primer – An Overview for Environmental Health Professionals.* <http://www.atsdr.cdc.gov/HAC/landfill/html/intro.html>