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<ktopping@calpoly.edu>, "ahill@co.slo.ca.us"
<ahill@co.slo.ca.us>, "frenchbicycles@gmail.com"
<frenchbicycles@gmail.com>, "darnold@co.slo.ca.us"
<darnold@co.slo.ca.us>, "elcarroll@co.slo.ca.us"
<elcarroll@co.slo.ca.us>, "fmecham@co.slo.ca.us"
<fmecham@co.slo.ca.us>, "rhedges@co.slo.ca.us"
<rhedges@co.slo.ca.us>, "boardofsups@co.slo.ca.us"
<boardofsups@co.slo.ca.us>, "cray@co.slo.ca.us"
<cray@co.slo.ca.us>, "lreynolds151@gmail.com"
<lreynolds151@gmail.com>, "stolpman@hotmail.com"
<stolpman@hotmail.com>
Date: 11/23/2014 10:52 AM
Subject: p66 Railspur Comment: Valley Fever

Dear Mr. Wilson:

I have reviewed the Phillips Refinery REIR information and feel that there is an important epidemiological issue that has not been addressed, namely, Valley Fever, or Coccidioidomycosis.

I have been a practicing physician assistant in San Luis Obispo County for 30 years and have seen a number of cases of "cocci" and am aware of an increase in cases over the last few years. I have confirmed this with the SLO Public Health Department epidemiologist and herein have included numerous links to pertinent articles, including the SLO Public Health Dept. dedicated "cocci" web page.

Coccidioidomycosis, "Valley Fever," is a fungus that is spread by way of spores that become airborne when soil is disrupted. Most cases of the disease are limited only to the lungs and cause pneumonia-like symptoms that eventually clear. However, the disease may "disseminate" and cause widespread organ involvement and possible death. There are certain higher risk groups depending on age, sex and ethnicity.

Specifically, I am concerned about the volume of soil that stands to be disturbed during construction of the proposed "rail spur" at the P-66 refinery. Referencing pages 4.3-35 -4.3-41 in the REIR, I cannot find any specific quantification of yardage of dirt that stands to be disrupted during grading, construction and berm building, but I imagine it would be substantial. Moreover, my understanding is that the predominant direction of wind flow during daytime hours is toward populated areas of the Mesa and greater NIpomo, which would tend to put those areas at potential risk of exposure to "cocci." Additionally, the workers on site, both construction workers and permanent workers at the refinery would be exposed depending on ambient conditions. I do not know if the fugitive dust emission mitigation plan is adequate to protect these individuals. The REIR states that with mitigation measures, such as soil dampening, there would be "61% fugitive dust control," but I do not find any specific information suggesting that the threat of "cocci" infection was taken into account or addressed.
Moreover, climatic conditions such as rainfall, especially after a period of drought causes "cocci" spores to germinate, bringing up the question of whether dampening soil might actually aggravate a potential problem.

MCK-01

Additional articles that I have included speak to the increase in cases of "cocci" associated with the recent construction of the solar plant in California Valley as well as an increase in cases involving workers at Camp Roberts during construction in 2010.

MCK-01 cont

Thank you for your time and for the opportunity for me to comment on this proposed project.

San Luis Obispo Public Health Epidemiologic Profile of Cocci:
http://www.slocounty.ca.gov/Assets/PH/Epidemiology/Epi+Profile+of+Cocci.pdf

SLO Public Health Dept Cocci site:
http://www.slocounty.ca.gov/health/publichealth/commdisease/Cocci_in_SLO_County.htm

SLO Public Health Power Point link re Cocci:

San Luis Obispo County Health Commission Presentation, April 2007

Camp Roberts outbreak: Epidemiology and Infection (2010) 138:507-511 Cambridge University Press

Calif Dept of Public Health Recommendations re Cocci:
http://www.slocounty.ca.gov/Assets/PH/Epidemiology/Cocci+Recomendations.pdf

LA Times article re Solar Farm workers sickened:
http://articles.latimes.com/2013/may/01/local/la-me-ln-valley-fever-solar-sites-20130501

Recommendations re Cocci exposure protection for workers:
http://www.cdph.ca.gov/programs/ohb/Documents/OccCocci.pdf

Climate factors influencing Cocci:
http://www.ehponline.org/members/2005/7786/7786.html

Sincerely,

Kevin J. McCarthy, PA-C
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Student Health Center
Cal Poly University
#1 Grand Ave.
San Luis Obispo, CA
93407
756-6039 (work)
481-5618 (home)

11/23/2014

*See 11/23/2014 Comment Letter
Sent via e-mail for Coding

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Epidemiologic Profile of Coccidiodomycosis

in

San Luis Obispo County, CA

1996-2012

San Luis Obispo County Public Health Department

May, 2014

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Introduction

This report is an Epidemiologic Profile of Coccidioidomycosis (Valley Fever, or "cocci"), in San Luis Obispo County (SLO County), California. Coccidioidomycosis is endemic in San Luis Obispo County, and since 2005, an average of 128 cases have been reported each year to County residents. It is estimated that between 30-60% of all residents in an endemic area are exposed to the Coccidioidomycosis fungus, thus potentially exposing between 8 1,000 and 162,000 residents of San Luis Obispo County to the disease. Although 60% of those infected show little or no symptoms, of those who are diagnosed from symptoms, more than 40% need to be hospitalized. With the average cost of a Cocci hospital stay averaging almost $50,000, the importance of diagnosing and treating the disease early cannot be overstated.

This report covers reported Coccidioidomycosis cases in SLO County during the period 1996 to 2012. The report attempts to describe "cocci" in terms of its occurrence, transmission and impact. The goal in providing this information is to help community-based organizations, planners, and policy-makers in evaluating programs and policies involving Coccidioidomycosis for the county and to increase the community's general awareness of the impact of Coccidioidomycosis in San Luis Obispo County.

Data Sources and Limitations

When viewing this report, please keep in mind the following:

1. The data represents those Coccidioidomycosis cases reported to the San Luis Obispo County Public Health Department by private physicians, laboratories, and State Institutions. It is not considered reflective of the total number of cases of Coccidioidomycosis, as there are undetected and unreported cases in the county. The data only reflects current reporting practices.

2. Due to confidentiality issues, when a category of persons being reported would result in a small number of cases, categories were collapsed to protect confidentiality. For example, some racial categories were collapsed to "Other" in figures. This condensation of data is done to protect confidentiality only, and is not meant to show any greater or lesser significance placed on any demographic or geographic group.

3. The data corresponds to cases reported between the years 1996-2012. However, the majority of cases were reported between the years 2002-2012. In 2010, labs were mandated by the state to report positive "cocci" cases to county public health departments. Before the mandate, Coccidioidomycosis cases were reported by clinical providers alone. Thus, increases in Coccidioidomycosis rates subsequent to the changes

made in 2010 did not necessarily reflect an increase in transmission of the fungus, but are more likely related to changes in reporting.

4. When geocoding cases to determine rates by zip code tract and census tract, results varied. Some cases geocoded by zip code were unable to be placed due to use of PO boxes. When PO boxes were in rural communities with large zip code areas, they were assigned to the enclosing community zip code. For example, for a case with a Shandon PO box, the case would be able to be assigned to the encompassing zip code surrounding Shandon. For large cities with multiple possibilities, they were excluded from the analysis. In geocoding to census tracts, some addresses were unavailable. In rural communities, where a zip code was available, and entirely contained within a census tract, the location was randomly placed in the census tract. Thus, rural rates have a lower error rate. Urban cases had a higher exclusion rate, which could have impacted urban rates per 100,000. However, with higher population rates in urban areas, this may not have had a significant impact.

San Luis Obispo County Overview

Located 200 miles north of Los Angeles and approximately 230 miles south of San Francisco, San Luis Obispo County is on the Central Coast of California. SLO County covers 3,316 square miles and, according to the California Department of Finance 2010 Census estimates[1], had a population of 269,637 in 2010, with 81% living in an urban area and 19% residing in a rural area. The population from 2000 to 2010 rose 9.3%.

The land area, according to the 2010 Census, is 3,299 square miles[2]. SLO County is primarily an agricultural area, devoting 61.6% of the land to farming. The population density according to the 2012 census is an average of 82 people per square mile.

According to the 2010 Census, the San Luis Obispo population is comprised of a variety of races. The majority (82.6%) of the San Luis Obispo residents identify as White. Additionally, 2.1% identify as Black or African American, 3.2% as Asian, 3.8% as two or more races, 7.3% other races, 0.1% Native Hawaiian and other Pacific Islander and 0.9% American Indian and Alaska Native. The median age of residents is 39 years old. Persons over 65 years of age make up 15.2% of the population, 61.4% of individuals are between 20 and 64 years old, and 4.9% are under 5 years old[1].

The 2010 Census reports a nearly equal gender distribution in SLO County, with 51% of the population male and 49% female[1]. More than three-fourths of the San Luis Obispo population identify as White[1].

There are currently two local correctional facilities in SLO County: the California Men's Colony near San Luis Obispo and the Atascadero State Hospital in Atascadero. Prior to 2008, a third facility, the El Paso de Robles Youth Correctional Facility in Paso Robles, operated in the North County, but has since been closed. These correctional facilities were and remain strictly male-only.

Valley Fever Background

Valley Fever (Coccidioidomycosis or "cocci") is an infection caused by a fungus, *Coccidioides*. The fungus inhabits soil and dirt in arid climates—areas with sparse rainfall and high temperatures—typical to the southwestern United States and northwestern Mexico. "Cocci" is especially prevalent in Arizona and California. *Coccidioides* predominantly affects the lungs, producing flu-like symptoms. In most cases, symptoms resolve themselves; however, severe forms of the illness can be fatal. The map below shows the endemic regions of the United States, which includes San Luis Obispo County. There have been an estimated 150,000 infections in the endemic areas each year[4].

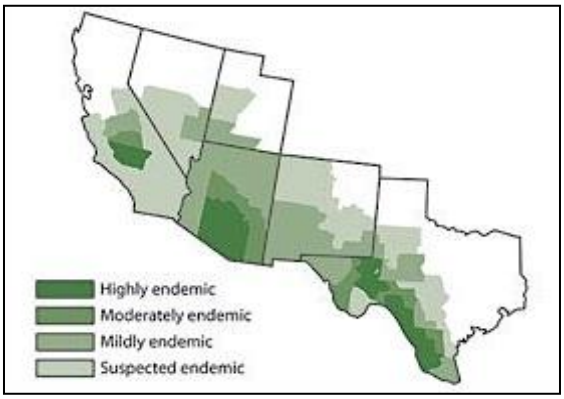


Figure 1. Valley Fever-Endemic Regions in the United States[3].

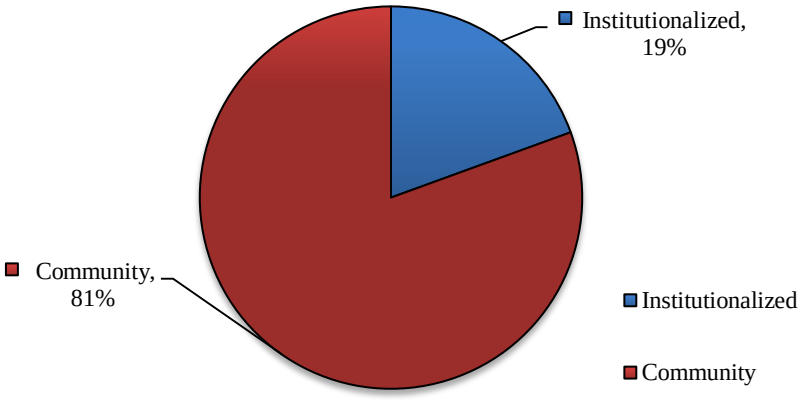
Valley Fever is contracted by breathing in dust containing a form of the *Coccidioides* fungus, called spores, which are too small to see. When soil housing *Coccidioides,* is disturbed, the fungal spores, called arthrospores, become airborne and can be inhaled by people or animals. Anyone who lives, works or travels in an area with Valley Fever is susceptible to infection. When a spore is inhaled, it transforms into a larger, multi-cellular structure, called a spherule, which continues to grow until it bursts, releasing more spores, called endospores, that grow into more spherules. Although the soil form of fungal spore can infect people and animals, the spherule form of the fungus cannot, and thus Valley Fever is not contagious between people or animals infected with the disease.

Almost two thirds of infected individuals exhibit no symptoms, experience only mild symptoms, and/or do not receive treatment. The remaining 40% of people show symptoms that closely resemble that of the flu or pneumonia, including fatigue, cough, chest pain, fever, rash, headache, and joint aches. In 1-2 percent of cases, the disease spreads, or disseminates, to other parts of the body, usually the skin. The disseminated infection can affect meninges, soft tissues, joints and bones. Although Valley Fever is generally a self-resolving infection, a small percentage of cases, less than 1%, are fatal. Due to lack of funding, a vaccine has not yet been developed for Valley Fever, but typically, Coccidioidomycosis is treatable with antifungal medications.

Coccidioidomycosis in San Luis Obispo County Correctional Facilities

There are currently two local correctional facilities operating in San Luis Obispo County: the California Men's Colony near San Luis Obispo, and the Atascadero State Hospital in Atascadero. Prior to 2008, a third facility, the El Paso de Robles Youth Correctional Facility in Paso Robles operated in the North County, but was closed. Valley Fever cases that occur in institutions are generally not reflective of community cases. To help highlight the differences, case occurring in institutions and cases occurring in the community are broken out separately.

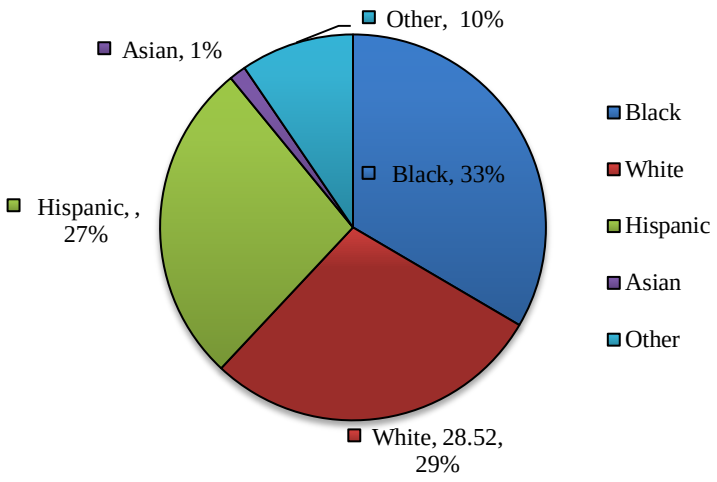
Figure 2.1. Percentage Coccidioides Reported in Community vs. Correctional Facility Cases in SLO County, 1996-2012.



Race and Ethnicity in institutionalized cases

The San Luis Obispo correctional facilities house inmates of diverse racial backgrounds. One third of SLO County correctional facility Coccidioidomycosis cases reported are from African American inmates, while nearly another third is attributed to Hispanic inmates. White cases account for twenty-nine percent of "cocci" cases. Ten percent of SLO County institutional cases fall under "other," which corresponds to races including: Native American, Native Hawaiian or other Pacific Islander, mixed race, unreported or other.

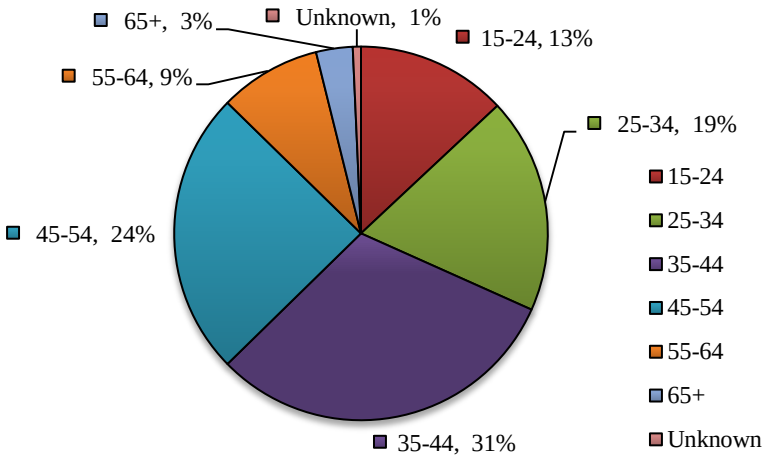
Figure 2.2. Institutionalized Race Demographics for Coccidioidomycosis in SLO County from 1996-2012.



Age in institutionalized cases

The State correctional facilities in San Luis Obispo house inmates of a variety of age groups. Nearly three-quarters of Coccidioidomycosis cases reported between 1996-2012 were within the ages of 25-54. The percentage of correctional "cocci" cases attributed to inmates 65 years or older was minimal. There were no "cocci" cases in correctional facilities for persons ages 0-14.

Figure 2.3. Institutionalized Age Demographics for Coccidioidomycosis in SLO County from 1996-2012.



Summary for Correctional Cases

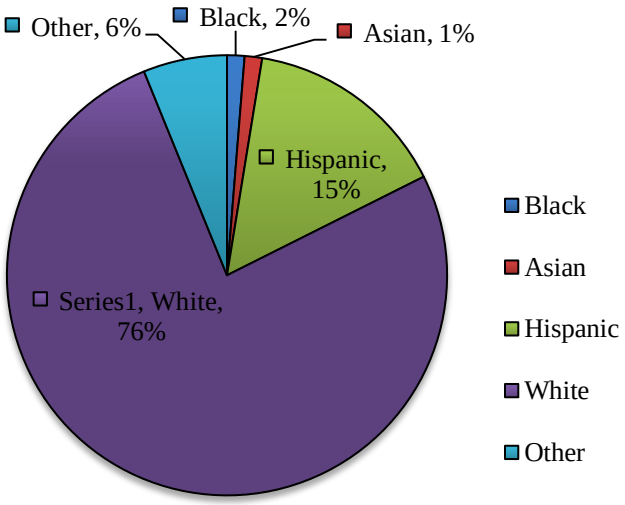
The San Luis Obispo State correctional facilities house a diverse population of inmates. Between the years 1996-2012, a total of 1,460 Coccidioidomycosis cases were reported to the San Luis Obispo County Public Health Department, of which 284 came from institutions. No San Luis Obispo County correctional facility cases were reported in the year 1998. It is not believed that there were no occurrences of "cocci" at correctional facilities in 1998; there is a possibility that the SLO County facilities did not have the time to report cases that year. Nearly twenty percent of all Coccidioidomycosis cases reported in the County of San Luis Obispo were accounted for by local correctional facilities. Additionally, one third of SLO County correctional facility Coccidioidomycosis cases reported were attributed to African American inmates and nearly another third were attributed to Hispanic inmates. The age range that had the highest number of reported Coccidioidomycosis cases were inmates between 35-44 years old. Valley Fever cases occur more frequently in two San Joaquin Valley prisons: Avenal and Pleasant Valley state prisons. About two-thirds of Valley Fever cases identified among California's state prisoners from 2008 to 2012 occurred in Pleasant Valley and Avenal state prisons[5]. These prisons, which hold a combined 8,100 inmates are approximately 10 miles apart and 75 miles northeast of San Luis Obispo and 175 miles southeast of San Francisco. Inmates that are deemed more susceptible to Coccidioidomycosis, including those with a higher risk of disseminated "cocci" or have depressed immune systems such as those who are HIV-positive or undergoing chemotherapy are sometimes transferred to SLO correctional facilities. Therefore, case counts in San Luis Obispo County could be inflated. Inmates could have become infected at their previous correctional facility, and then diagnosed during their tenure in San Luis Obispo County facilities.

Coccidioidomycosis in the San Luis Obispo County Community

Race demographics in community cases of Valley Fever

The San Luis Obispo community population is comprised of a variety of races. According to the 2010 census, 82.6% of the San Luis Obispo residents identified as White. Additionally, 2.1% identified as Black or African American, 3.2% as Asian, 3.8% as two or more races, 7.3% other races, 0.1% Native Hawaiian and other Pacific Islander and 0.9% American Indian and Alaska Native[1]. Between the years 1996-2012, nearly seventy-five percent of Coccidioidomycosis cases in the San Luis Obispo community were attributed to White persons, fifteen percent to Hispanic individuals, and the remaining nine percent to Black, Asian and "other."

Figure 3.1. San Luis Obispo County Community Coccidioidomycosis Cases by Race.



Age demographics in community cases of Valley Fever

San Luis Obispo County is home to individuals of all ages. Between the years 1996-2012, Coccidioidomycosis case rates in the San Luis Obispo County community were highest among those aged 41-60. Incidence rates dropped significantly for persons ages 0-10 and above 80 years of age.

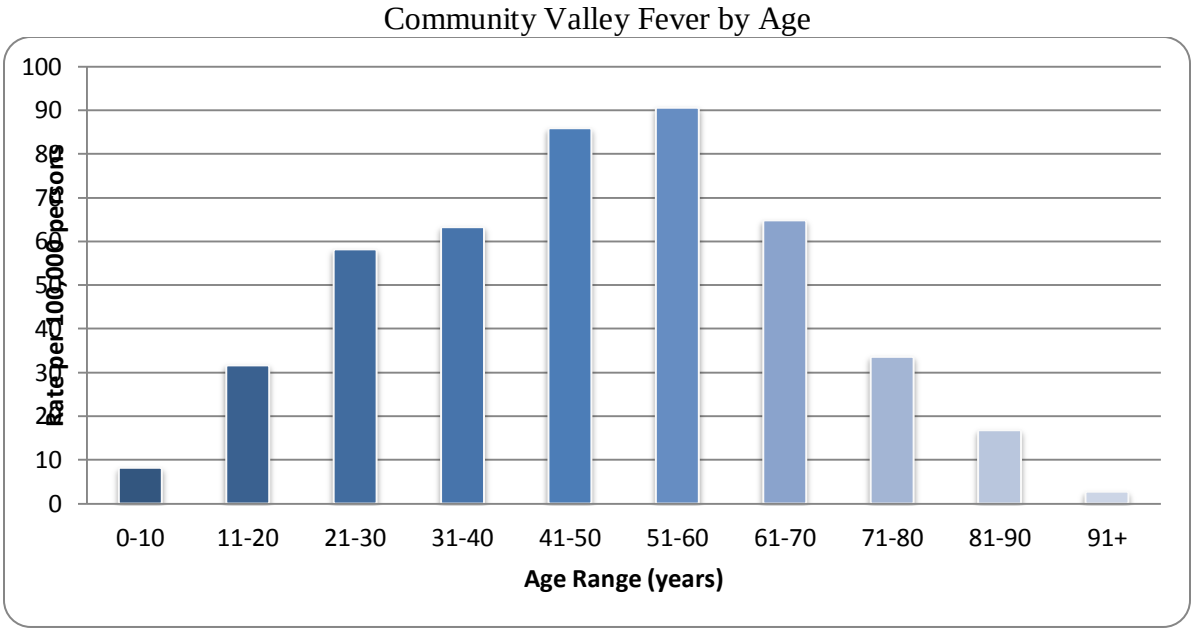


Figure 3.2. Rate of Coccidioidomycosis in SLO County Community by Age.
Valley Fever cases per 100,000 by age.

Gender demographics in community cases of Valley Fever

Based on the 2010 Census, San Luis Obispo's gender distribution showed a population that was 51.2% male and 48.8% female[1]. Between 1996-2012, males showed a higher number of reported cases of Coccidioidomycosis than females in the community. Male Coccidioidomycosis cases made up 65% of community cases during that 17-year period. One possible explanation for this is that males typically are employed in outside job categories such as construction and agriculture more than females.

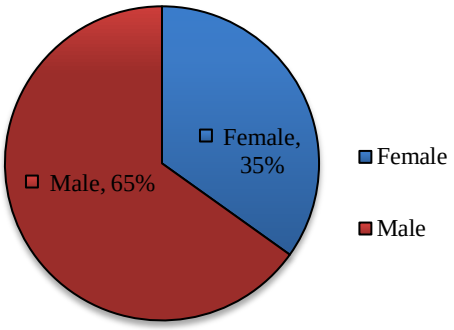


Figure 3.3. Valley Fever rates by gender in SLO County, 1996-2012

The number of Valley Fever cases by gender varied significantly between 1996-2012. There were consistently more male cases reported than female cases, approximately twice as many each year. There were increases in reported cases around 2004 and again in 2010, when labs were mandated to report "cocci" cases.

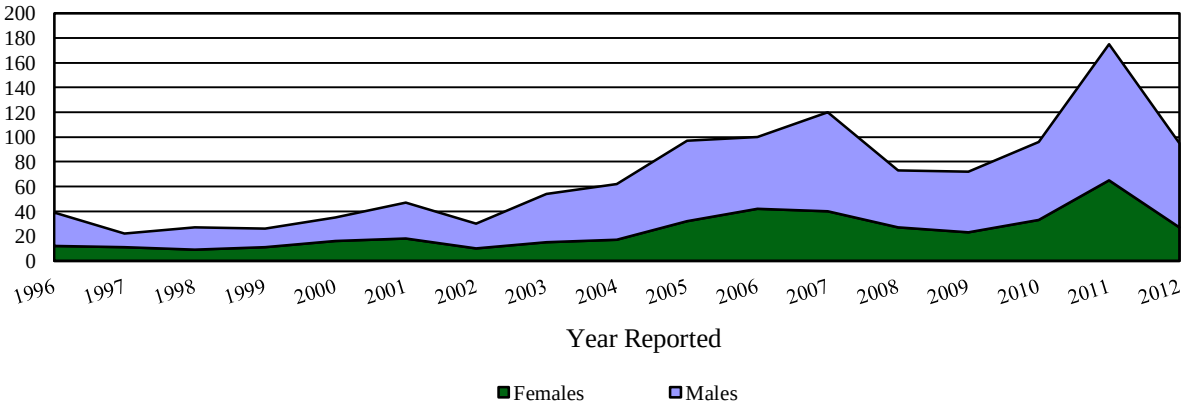


Figure 3.4. Coccidioidomycosis Cases by Gender per Year in SLO County Community.

Year of diagnosis in community cases of Valley Fever

Between the years 1996-2012, there was an increasing trend in the number of reported Valley Fever cases per year. In 2010, the number of cases of Valley Fever reported increased, corresponding to the implementation of the State mandate requiring labs to report Coccidioidomycosis cases. Additionally, between the years 2002 to 2007 there was a steady increase in reported "cocci" cases in the San Luis Obispo community. This trend was consistent with a Statewide increase in cases for that time period. Figure 3.5 shows the number of cases of Cocci reported by year.

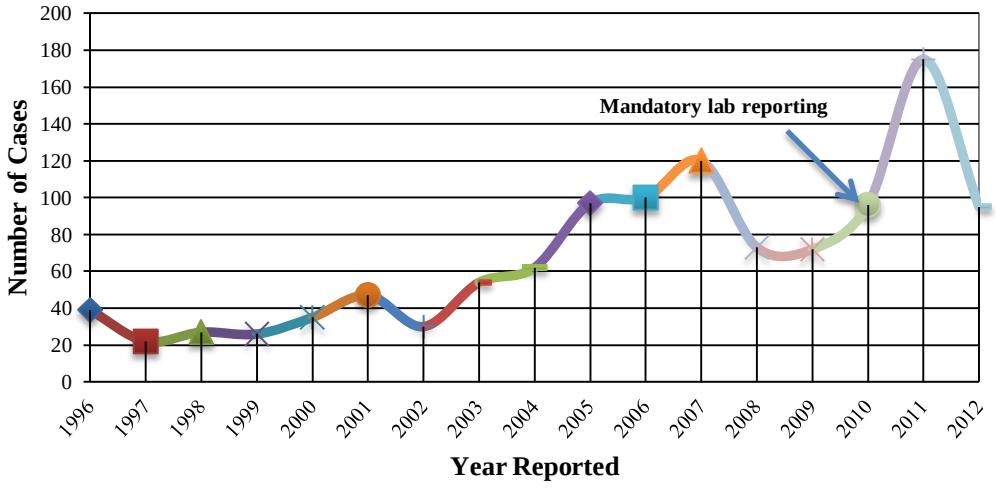


Figure 3.5. SLO County Community Coccidioidomycosis Cases Reported by Year.

Summary of Community Cases

From 1996-2012, San Luis Obispo reported 1176 Valley Fever cases among the community, 81% of all cases reported in the county. Coccidioidomycosis rates were highest in the community among persons between 41-60 years of age. Additionally, roughly three-quarters of "cocci" cases in the San Luis Obispo community were attributed to White individuals, fifteen percent of cases identified as Hispanic, and the remaining nine percent of cases specified the races: Black, Asian and "other." Although roughly half of the San Luis Obispo population was male (51.2%), nearly two-thirds (65%) of Valley Fever community cases that were reported between 1996-2012 were attributed to males. Over the seventeen-year span, the number of Valley Fever cases in males was nearly twice that of female cases every year. The number of reported Coccidioidomycosis cases in the San Luis Obispo community increased over the years 1996-2012. In 2010, the state mandated that labs report positive "cocci" cases, which corresponds to the sharp increase of cases that year.

Coccidioidomycosis in San Luis Obispo County

Institutions vs. Community

With the presence of two current institutions housing inmates in the San Luis Obispo County, it is important to look at both community and institutional populations separately, as demographics differ between the two populations. The entire institutional population is male in San Luis Obispo and a higher percentage of inmates are African American and Hispanic compared to the community. Between the years 1996-2012, there were approximately 45 Valley Fever cases per 10,000 persons reported among the San Luis Obispo community, and 10 per 10,000 persons reported in correctional facilities.

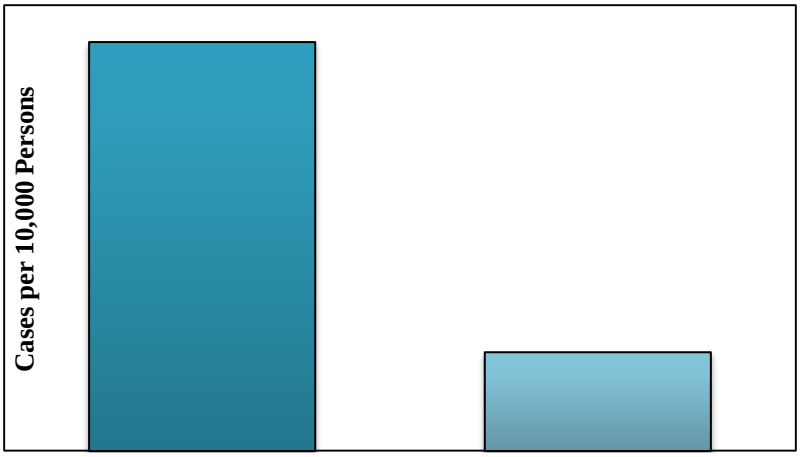
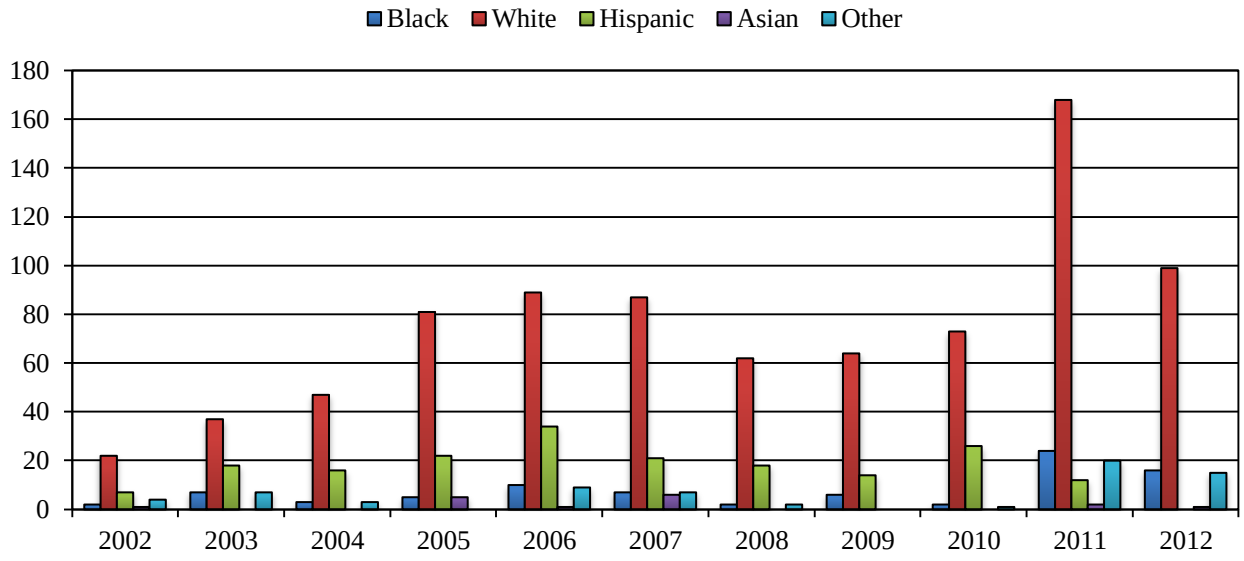


Figure 4.1: Coccidioidomycosis Rates per 10,000 in SLO County Community vs. Correctional Facilities 1996-2012.

In San Luis Obispo County between 2002-2012, the majority of Valley Fever cases were reported in 2011 and 2012, the years following the 2010 state mandate for labs to report "cocci" cases. Additionally, the race that had the highest incidence of "cocci" between that 17-year period in SLO County was the White population, followed by the Hispanic population.

Figure 4.2. Coccidioidomycosis by Race per year in SLO County, Community and Correctional. "Cocci" by race, year in SLO County.



San Luis Obispo vs. California

The California State Valley Fever statistics vary from the SLO County Data. The main distinction is the general upward trend in cases in California. In San Luis Obispo County, yearly change, while the general trend is increasing, some years show dramatic peaks. These differences are likely due to the small population size of SLO County compared to the state as a whole. Small changes in the SLO rate of incidence would show a large graphical change, whereas the same change in a larger population would hardly change the graph. The number of California state-reported cases has steadily risen since 1996 and an increasing trend in SLO County has been shown as well. Coccidioidomycosis became lab reportable in 2010, helping to explain some of the increase in Valley Fever cases after that year.

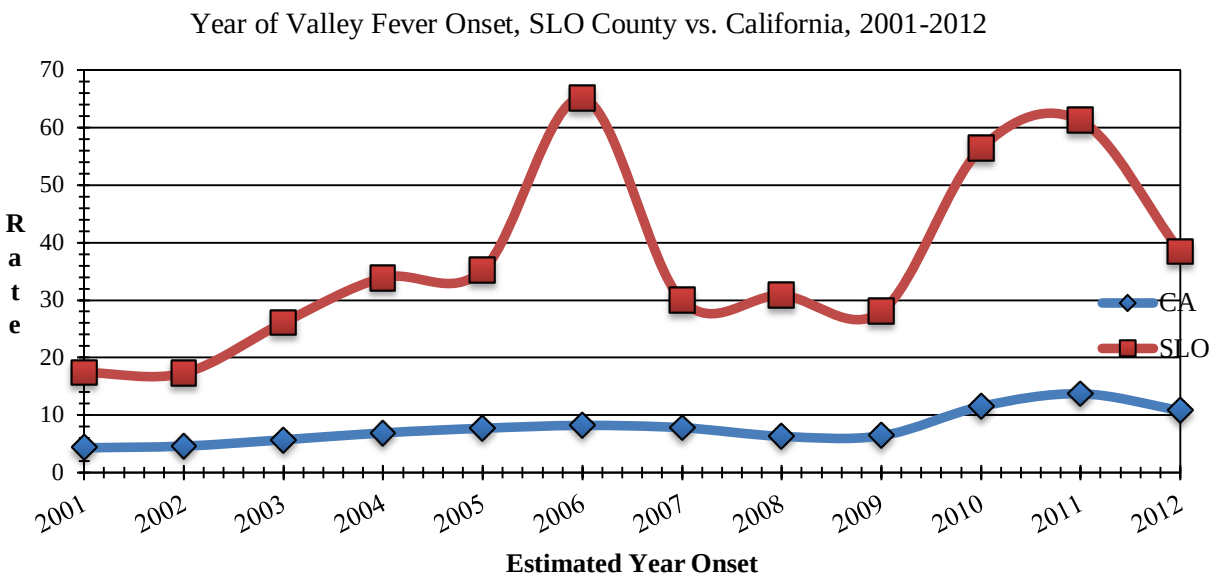


Figure 4.3. Year of Valley Fever Onset, SLO County vs. California, 2001-2012[6].

Weather

Between 1996-2012, summer months in San Luis Obispo County consistently experienced less than one inch of rainfall. The combination of the lack of rain and warmer temperatures in the summer provided an ideal climate for the spread of *Coccidioides*. *Coccidiodes* multiplies in the soil during the rainy season, but during the dry, windy season, can become airborne, thus increasing the chance a spore will be inhaled. In drought years, the fungus remains dormant, and does not multiply in the soil. When a period of drought is followed by rainfall, a spike in cases is generally seen. In SLO County, the majority of onset occurred in the later part of the year, after the summer months with the lowest amount of rainfall.

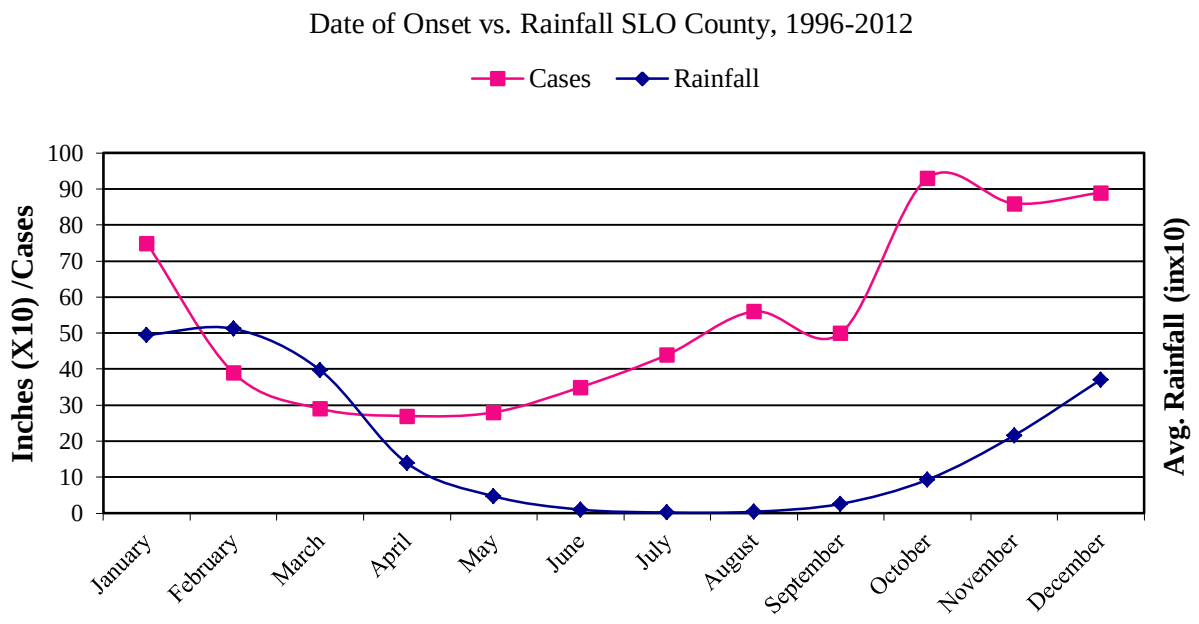
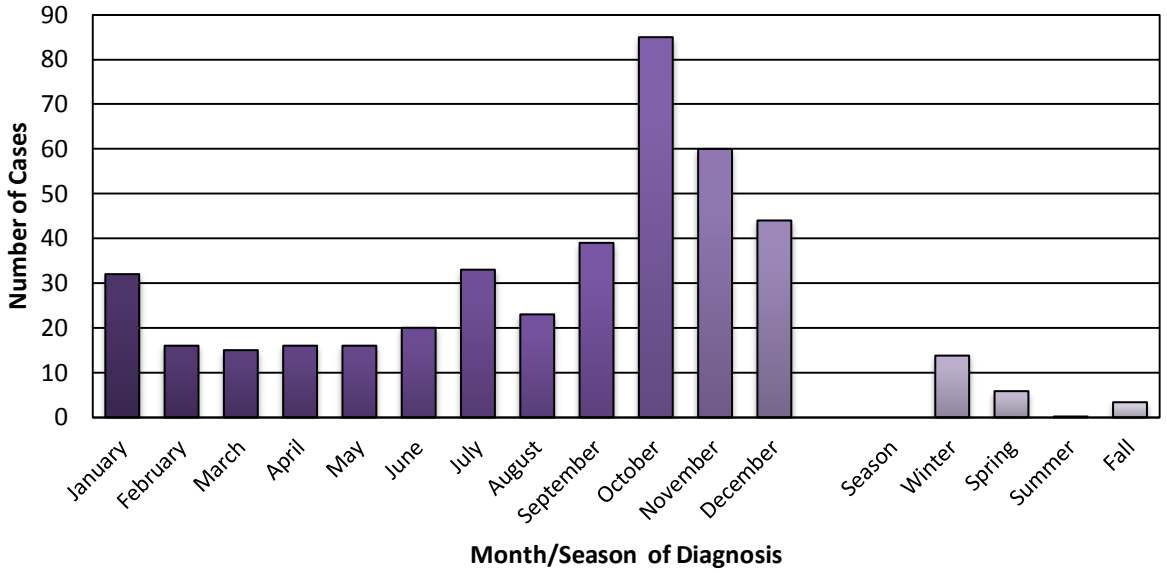


Figure 4.4. Date of Onset vs. Rainfall SLO County, 1996-2012. Average monthly rainfall vs. date of onset for "cocci" in SLO County. The average inches of rainfall per month in San Luis Obispo, CA was compared to the number of cases per month[7].

Season/Month

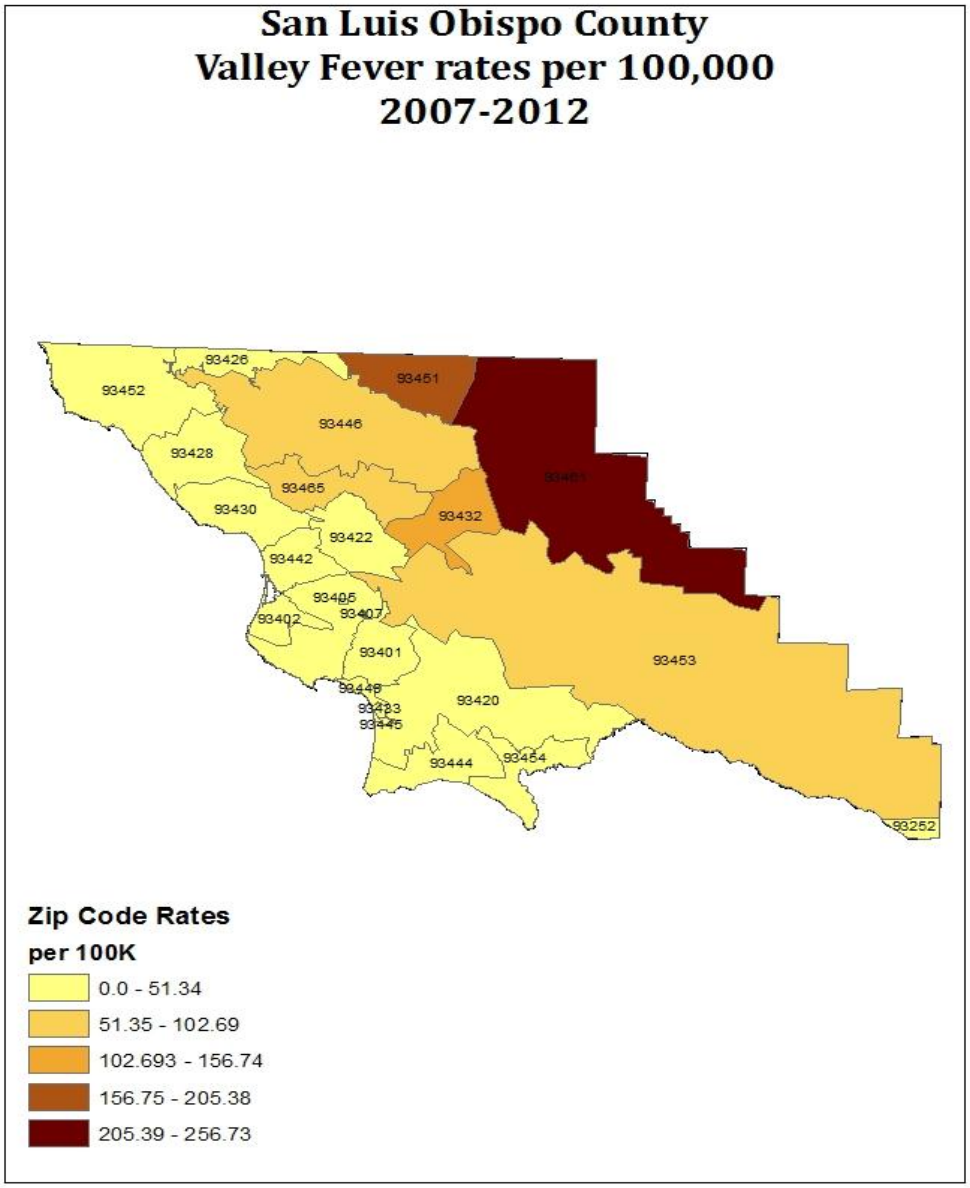
For purposes of seasonal comparison, each season will be defined by a three month period of time. December, January, and February are winter; March, April, and May are spring; June, July, and August are summer; and September, October, and November are fall. The fall season shows the greatest number of cases. The number of cases begin rising in the fall, and peak in October, and then declines in the winter. Because there is often a delay in diagnosis of Valley fever, the increased reporting of cases in the fall can indicate that individuals diagnosed with Coccidioidomycosis contracted it in the previous summer months. Symptoms do not arise immediately, if at all, so the reported date of onset for the disease is generally weeks or months after infection. In addition to the slow onset of symptoms, there can be a delay in correctly diagnosing Valley Fever in a patient. Valley Fever is not widely recognized, leading doctors to sometimes falsely diagnose the disease and further delay accurate diagnosis.

Figure 4.5. Date of Diagnosis Statistics for Coccidioidomycosis in SLO County for Community and Correctional.

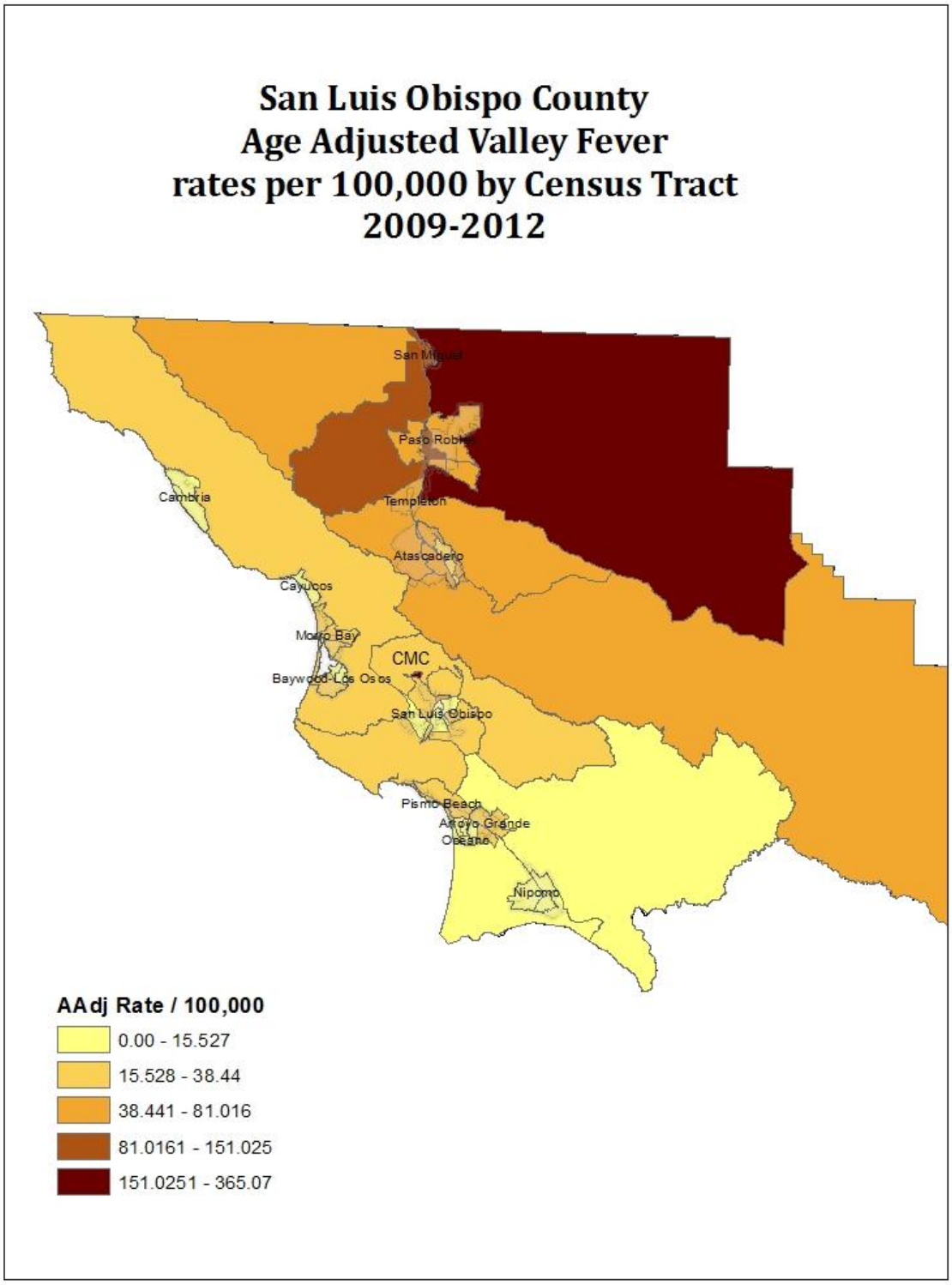


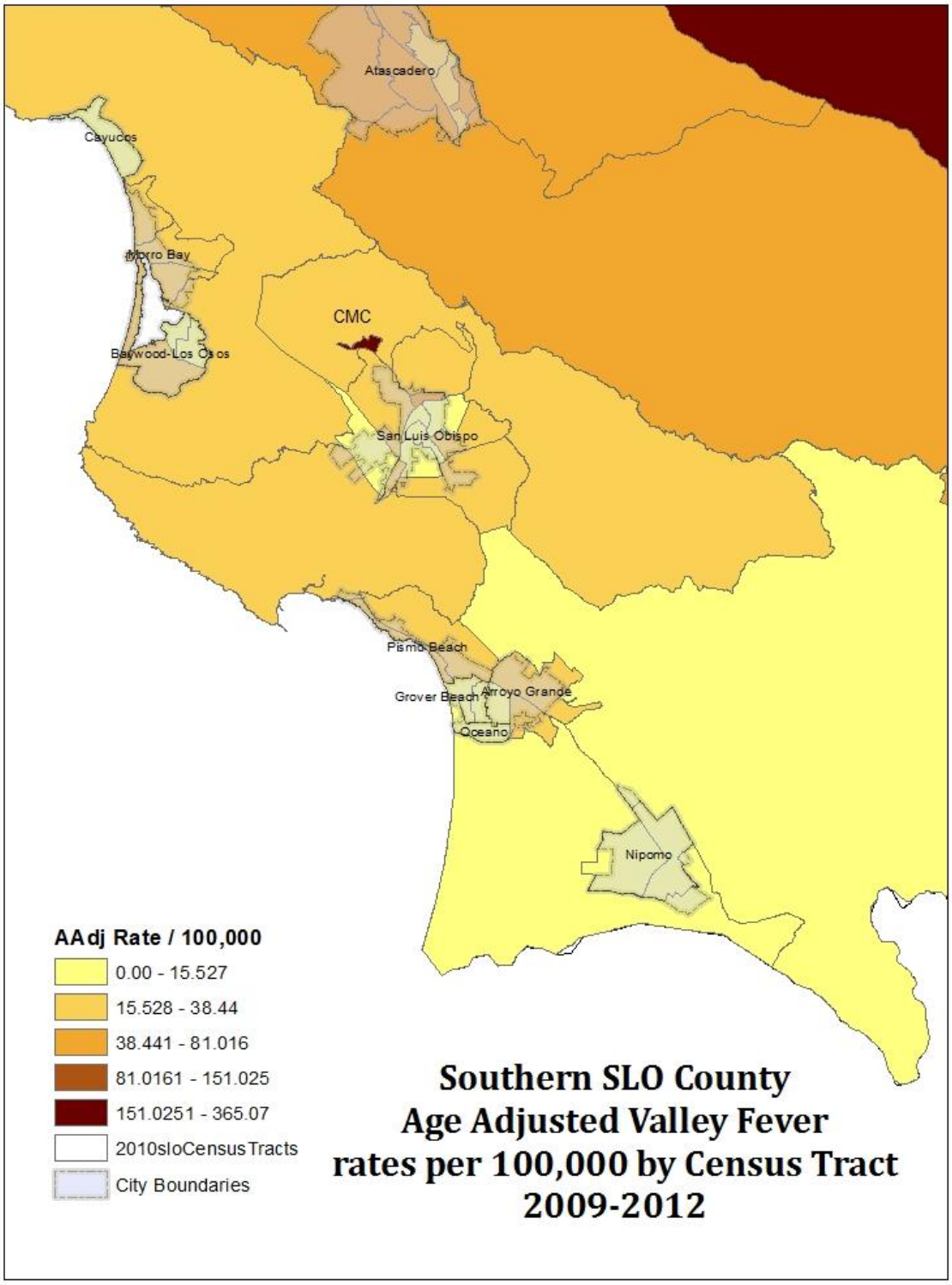
Regional rates of infection

Reported cases, and rates per 100,000 persons vary in San Luis Obispo County by region. On the following page, a map of San Luis Obispo County is shown, with crude case rates per 100,000 persons calculated for zip codes in the County. Age adjusted rates are unable to be calculated due to lack of age breakdown data for Zip Code Tract Areas (ZCTAs) from the Census. Population size for each zip code was obtained from the 2010 US Census ZCTAs. Of the 757 community cases identified between 2007 and 2012, only 7 had no address data that allowed for placement in a zip code. Rates in the northeast region of the County were highest, with the southeast also showing elevated rates. The coastal regions had lower rates overall.

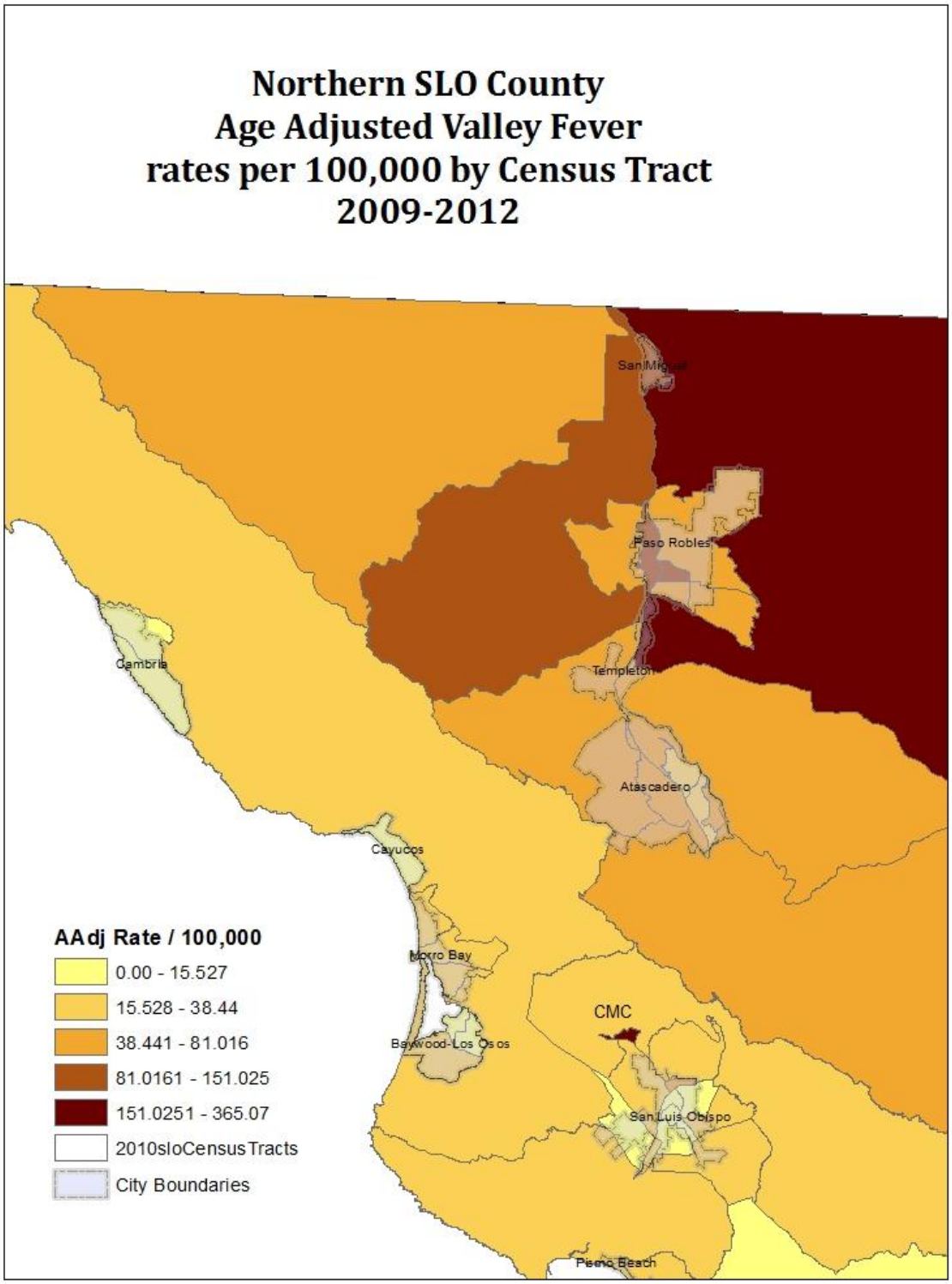


On the following pages, age-adjusted rates by census tract are shown for San Luis Obispo County for the years 2009-2012. Greater detail of North County and South County follow.


San Luis Obispo County
Age Adjusted Valley Fever
rates per 100,000 by Census Tract
2009-2012
San Miguel
Paso Robles
Cambria
Templeton
Atascadero
Cayucos
Morro Bay
CMC
Baywood-Los Osos
San Luis Obispo
Pismo Beach
Arroyo Grande
Oceano
Nipomo
AAdj Rate / 100,000
0.00 - 15.527
15.528 - 38.44
38.441 - 81.016
81.0161 - 151.025
151.0251 - 365.07



The map above shows greater detail of the SLO, coastal and South County regions. Here, CMC is the high rate census tract shown to the north of SLO. The City boundaries help illustrate how many census tracts can be in a city, but very few comprise the more rural portions of the County.



The map above shows the greater detail of the North County and coastal regions. It also shows the eastern portion of Paso Robles with higher rates of Cocci than the western portion. The explanation for this is unknown.

Conclusion

Valley Fever has important medical, demographic, and financial implications for the state. According to the University of Arizona Valley Fever Center for Excellence, most cases of Valley Fever are so mild that over 60% of those infected with the fungus exhibit no symptoms or experience flu-like symptoms and do not seek medical attention. Common Valley Fever symptoms are not unique to the disease and so it can be easily misdiagnosed. Identifying Coccidioidomycosis as the cause of illness requires specific laboratory testing[8].

Although no specific age, sex or gender is more at risk for developing Valley Fever, certain demographics have a higher risk of the infection spreading to other parts of the body (dissemination). Men have a higher rate of dissemination than do women. Additionally, studies have shown that the rate of dissemination in African Americans and Filipinos is higher than the rest of the U.S. population. Other persons that have an increased risk of disseminated Coccidioidomycosis are those with immune system deficiencies such as patients with diabetes, pregnancy, Hodgkin's disease or are positive for HIV[9].

Caused by inhaling fungal spores, Coccidioidomycosis costs the state prison system about $23 million annually in inmate health care. Additionally, a class action lawsuit has been opened on behalf of current and former inmates who contracted the disease while in prison[10]. On the map of age-adjusted rates by census tract, CMC is represented by its own census tract, and shows up as a high rate region within the lower rate region surrounding San Luis Obispo.

In 2013, an outbreak of Valley Fever resulted in over 50 cases of Coccidioidomycosis among workers at two solar power construction sites in San Luis Obispo County. Valley Fever illnesses occurred among workers building the solar farms in the eastern portion of the County known as California Valley[11]. A similar construction-related outbreak at Camp Roberts in 2007 resulted in over 90% of the work crew becoming infected with Valley Fever. Workplace exposure may be more prevalent than thought, and have implications for workplace safety and prevention in outdoor industry.

There is currently no vaccine for Valley Fever, and the only prevention is to avoid inhaling dust or dirt. The risk of infection can be lessened by staying indoors on very windy days when dust or dirt are visible in the air. Anyone who lives in or visits an endemic area is at risk for contracting Valley Fever. There is no evidence that suggests any particular group of people is more or less at risk for disease.

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(9) "Valley Fever Center for Excellence." *Valley Fever Center*. University of Arizona, 2010. Web. 29 Mar. 2014.

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San Luis Obispo County, California

Coccidioidomycosis (Valley Fever) in San Luis Obispo County

Coccidioidomycosis (Valley Fever) in San Luis Obispo County

Coccidioidomycosis (aka, Valley Fever or Cocci) is endemic to San Luis Obispo County. San Luis Obispo County has conditions that are ideal for the growth of this fungal organism, with a generally arid climate, below 4,500 feet elevation, and sandy soil. What this means is that this fungus lives and grows in the soil of our County. There are many good websites out there that can give background information on what Cocci is, risk factors, testing, diagnosis and other information. Three are listed below:

http://www.cdc.gov/nczved/dfbmd/disease_listing/coccidioidomycosis_gi.html

http://www.vfce.arizona.edu/

http://www.doctorfungus.org/

This site is intended to provide information on the local burden of Valley Fever in San Luis Obispo County, and provide resources not necessarily found elsewhere. Below is a flyer with basic information regarding Valley Fever, symptoms, risks, and treatment.

Valley Fever Pamphlet

Epidemiologic Profile of Coccidioidomycosis for San Luis Obispo County:

Click on our Epidemiologic Profile to get a comprehensive look at the Epidemiology of Valley Fever between 1996-2012.

Occupational Data for cases reported in 2007 & 2008

		South County		North County	
		Count	Percent	Count	Percent

	TOTAL CASES	74		141	
	Occupation				
	Construction/ Landscape	6	8%	14	10%
	Minor Child	3	4%	3	2%
	Farming Equipment Operator	1	1%	2	1%
	Office Setting	4	5%	15	11%
	Food Service	1	1%	2	1%
	Correctional Facility*	22	30%	3	2%
	Disabled/ At Home	2	3%	13	9%
	Technical	1	1%	4	3%
	Firefighter	2	3%	1	1%
	Retail	3	4%	2	1%
	Healthcare	3	4%	3	2%
	Retired	6	8%	26	18%
	Student	3	4%	2	1%
	Truck Driver	0	0%	1	1%
	Industrial	2	3%	2	1%
	Other	15	20%	55	39%

*Correctional Facility primarily reflects inmate cases.

Local Presentations and/or resources:

Recommendations for workers to prevent infection by Valley Fever in SLO County: (PDF - 31K)

Average time lapse between infection and Laboratory Diagnosis of Coccidioidomycosis(From Kern County Data): (MS Excel File)

San Luis Obispo County Health Commission Presentation, April 2007 (This is a MS PowerPoint File)

Please note that the skin test is no longer used to diagnose Cocci, and if you suspect you have Cocci, as this chart shows, you may need to wait for several weeks to have laboratory confirmation of infection. However, these test data are informational only, and not meant to guide persons in their testing decisions.

Maps:

SLO County Cocci incidence, 2000-2007 -(PDF 149Kb, small format)

SLO County Cocci incidenct, 2000-2007 (PDF 675Kb, large format)

North County Cocci Incidence, 2000-2007 (PDF 299Kb, small format)

South County Cocci Incidence, 2000-2007[Link]

Articles of Interest:

Coccidioidomycosis – IDSA Guidelines -
http://www.journals.uchicago.edu/doi/pdf/10.1086/496991

Estimating Severe Coccidioidomycosis in California –

http://www.cdc.gov/eid/content/13/7/1087.htm

Point-Source outbreak of coccidioidomycosis in construction workers (Outbreak at Camp Roberts)- *Epidemiology and Infection (2010) 138:507-511 Cambridge University Press*

Annals of the New York Academy of Sciences issue : Vol 1111 Coccidioidomycosis Sixth International Symposium

http://www3.interscience.wiley.com/journal/117985869/issue

Coccidioidomycosis as a common cause of Community Acquired Pneumonia - http://www.cdc.gov/ncidod/EID/vol12n006/06-0028.htm

Climate Factors Influencing Coccioidomycosis Seasonality and Outbreaks -

http://www.ehponline.org/members/2005/7786/7786.html

During the Fall of 2007, San Luis Obispo County Public Health Department investigated an outbreak of Valley Fever (*coccidioides immitis*) in construction workers in the North County region of the County. The California Department of Public Health participated in the investigation, and the following recommendations were issued to limit exposure to Valley Fever. Certain words were removed from the recommendations, to make the location of the outbreak more generic in order to protect confidentiality.

As you know, the California Department of Public Health has been conducting an epidemiological investigation of the outbreak of Valley Fever among a construction crew October 2007. Although this investigation is ongoing, we are writing to recommend interim measures to control worker exposure to species of Coccidioides (cocci), the fungal agent that causes Valley Fever. These recommendations are based on scientific information from the published literature.

Cocci is spread in the environment through dust that contains spores of the fungus. Geographic areas that are more likely to contain cocci spores in the soil (endemic areas) include the deserts of California, Nevada, Arizona, New Mexico, and Texas, as well as Mexico. The spores are small enough to be inhaled deep into the lung, where they can cause infection (Coccidioidomycosis or Valley Fever). Construction workers have been found to be at increased risk of Valley Fever compared to agricultural and other workers. In particular, pipeline, highway, and utility construction often involves work in remote areas where the soil has not been disturbed and where pockets of cocci may exist. When these pockets are disturbed, the dust raised can have a high concentration of spores. These pockets cannot be reliably predicted, but preventive measures, notably dust control, can be effective in reducing the rate of infection and the seriousness of epidemics.

Based on the most recent incident and on past incidents, we know that San Luis Obispo County is an endemic area for cocci. Workers exposed to dust may be considered at risk for developing Valley Fever. We recommend that you implement the following control measures to reduce the possibility of worker illness:

1. Reevaluate and update your Injury and Illness Prevention Program (IIPP, as required by Title 8, Section 3203), and ensure that safeguards to prevent Valley Fever are included.
2. Train all employees on the following issues:
    - The soil in San Luis Obispo County may contain cocci spores, especially in the North County region;
    - Inhaling cocci spores may cause Valley fever;
    - How to recognize symptoms of Valley Fever; these symptoms resemble common viral infections, and may include fatigue, cough, chest pain, fever, rash, headache, and body and joint ache;
    - Work with a medical professional with expertise in cocci as you develop this training. More information about cocci infection is available from the following websites

- http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=845369
- http://www.vfce.arizona.edu/VFIH-home.htm
- Workers must promptly report suspected symptoms of work-related Valley Fever to a supervisor;
- Workers are entitled to receive prompt medical care if they suspect symptoms of work-related Valley Fever; workers should inform the health care provider that they may have been exposed to cocci;
- To protect themselves, workers should use control measure as outlined in this document.

3. Control dust exposure:
   - Consult with local Air Pollution Control District Compliance Assistance programs and with California Occupational Safety and Health Administration (Cal/OSHA) Compliance program regarding meeting the requirements of Dust Control Plans and for specific methods of dust control. These methods may include wetting the soil while ensuring that the wetting process does not raise dust or adversely affect the construction process;
   - Provide HEP-filtered air-conditioned enclosed cabs on heavy equipment. Train workers on proper use of cabs, such as turning on air conditioning prior to using the equipment.
   - Provide communication methods, such as 2-way radios, for use in enclosed cabs;
   - Provide National Institute for Occupational Safety and Health (NIOSH)-approved respirators for workers without a prior history of Valley Fever.
   - Half-face respirators equipped with N-100 or P-100 filters should be used during digging. Employees should wear respirators when working near earth moving machinery.
   - Employees should be medically evaluated, fit-tested, and properly trained on the use of the respirators, and a full respiratory protection program in accordance with the applicable Cal/OSHA Respiratory Protection Standard (8 CCR 5144) should be in place;
   - Prohibit eating and smoking at the worksite, and provide separate, clean eating areas with hand-washing facilities;
   - Avoid outdoor construction operations during unusually windy conditions;
   - Consider limiting outdoor construction during the Fall to essential jobs only, as the risk of cocci infection is higher during this season.

4. Prevent transport of cocci outside endemic areas:
   - Thoroughly clean equipment, vehicles, and other items before they are moved off-site to other work locations;
   - Provide workers with coveralls daily, lockers (or other system for keeping work and street clothing and shoes separate), daily changing and showering facilities.
   - Clothing should be changed after work everyday, preferably at the work site;
   - Train workers to recognize that cocci may be transported offsite on contaminated equipment, clothing, and shoes; alternatively, consider installing boot-washing stations;

- Post warnings onsite and consider limiting access to visitors, especially those without adequate training and respiratory protection.

5. Improve medical surveillance for employees:

- Employees should have prompt access to medical care, including suspected work-related illnesses and injuries;
- Work with a medical professional to develop a protocol to medically evaluate employees who have symptoms of Valley Fever;
- Consider preferentially contracting with 1-2 clinics in the area and communicate with the health care providers in those clinics to ensure that providers are aware that Valley Fever has been reported in San Luis Obispo County, and especially the North County region. This will increase the likelihood that ill workers will receive prompt, proper and consistent medical care;
- Respirator Clearance should include medical evaluation for all new employees, annual re-evaluation for changes in medical status, and annual training, and fit-testing;
- Please note that skin testing is not recommended for evaluation of Valley Fever;
- If an employee is diagnosed with Valley Fever, a physician must determine if the employee should be taken off work, when they may return to work, and what type of work activities they may perform.

Los Angeles Times | ARTICLE COLLECTIONS

← Back to Original Article

28 solar workers sickened by valley fever in San Luis Obispo County

May 01, 2013 | By Julie Cart

Epidemiologists are investigating an outbreak of valley fever that has sickened 28 workers at two large solar-power construction sites in San Luis Obispo County.

Staff from the California Department of Public Health, and investigators from the California Division of Occupational Safety and Health and San Luis Obispo County visited the sites near the Carrizo Plain two months ago, officials said.

They identified the sites as the Topaz Solar Farm and California Valley Solar Ranch, two large-scale photovoltaic power plants whose construction often requires considerable scraping and clearing to make way for thousands of acres of solar panels.

Valley fever, also known as *Coccidioidomycosis*, is contracted by breathing in fungal spores released when desert soils are disturbed. The illness is prevalent in many areas of the California desert and is common among agricultural workers and construction crews. It is not contagious.

Meanwhile, the state is attempting to stem an outbreak of valley fever that has resulted in dozens of deaths among prisoners in Central Valley prisons since 2006, according to an analysis conducted by Dr. John Galgiani, a professor of infectious diseases at the University of Arizona and a valley fever expert. Federal officials this week ordered the relocation to other prisons of more than 3,000 inmates considered vulnerable to the illness.

Galgiani said in an interview that he was unsure what was causing the cases, but he called upon state officials to contact the CDC for assistance in what he termed a "public health emergency."

Among the workers at the solar panel sites, less than half develop flu-like symptoms that include a cough, fever, chest pains and muscle aches that can persist for weeks. In extreme cases, valley fever can cause death, usually among patients with compromised immune systems.

State officials did not provide details about who contracted the illness at the solar sites, or where they live, citing medical privacy laws. But at least one case involves an electrical worker at the California Valley project.

Mark Simonin, business manager for the International Brotherhood of Electrical Workers, Local 639 in San Luis Obispo, said the electrician was digging into the ground with a claw hammer and inhaled dust. Simonin said the man became ill and a subsequent blood test confirmed valley fever.

The worker required breathing therapy treatment but didn't miss any time off the job, Simonin said.

Although respirators can prevent valley fever, workers laboring in harsh desert heat find the large commercial masks uncomfortable and are reluctant to wear them, Simonin said. He said the developer has done a good job keeping dust down on the site.

The threat of acquiring the respiratory illness extends to residents living near expansive construction sites. That risk is rising given the scope of the renewable energy boom centered in the state. Scores of solar projects are planned for millions of acres across California's Mojave Desert and elsewhere.

The Centers for Disease Control and Prevention announced in March that valley fever cases in the Southwest have increased by 90% from 1998 to 2011. California's increase mirrors that, with reported cases growing 71% over the decade 2001 to 2011.

Valley fever is a serious health issue and cases are required to be reported to state and federal health authorities. It is fatal in about 1% of cases.

A journal article published last year examined national death records from 1990 to 2008 and found 3,089 instances in which valley fever was the underlying or contributing cause of death. Nearly half of those deaths — 1,451 — occurred in California.

ALSO:

Woman found face-down on beach in Newport was slain

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Occupational Coccidioidomycosis in California

Outbreak Investigation, Respirator Recommendations, and Surveillance Findings

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Objective: To describe the investigation of a 2007 occupational coccidioidomycosis outbreak in California, recommend prevention measures, and assess statewide disease burden. **Methods:** We evaluated the worksite, observed work practices, interviewed the workers and employer, reviewed medical records, provided prevention recommendations including risk-based respirator selection, and analyzed statewide workers' compensation claims. **Results:** Ten of 12 workers developed acute pulmonary coccidioidomycosis; none used respiratory protection. We recommended engineering, work practice, and administrative controls, powered air-purifying respirator use, and medical care. Occupational coccidioidomycosis incidence nearly quadrupled in California from 2000 to 2006, with the highest rates in construction and agricultural workers. **Conclusions:** Construction workers are at risk for occupational coccidioidomycosis. The high attack rate in this outbreak was due to lack of awareness, rainfall patterns, soil disruption, and failure to use appropriate controls. Multiple risk-based measures are needed to control occupational coccidioidomycosis in endemic areas.

Coccidioidomycosis, also known as Valley Fever, is a recognized occupational illness. The Centers for Disease Control and Prevention[1] considers workers engaged in soil-disrupting activities, including military personnel participating in training exercises in endemic areas, to be populations at risk for the disease. Published studies[2–6] have documented occupational disease clusters in endemic areas among military personnel, anthropologists, and archaeologists. Increased disease incidence has been reported among agricultural workers in endemic areas.[7] In nonendemic areas, work-related cases of disease have been reported in various occupations, including laboratory and hospital personnel.[7–11] Coccidioidomycosis may cause disability lasting from days to months.[4]

Coccidioidomycosis is caused by the inhalation of airborne fungal spores from either of the two soil-dwelling *Coccidioides* species: *C. immitis*, native to California, and *C. posadasii*, found outside California. The fungus is endemic to certain semiarid areas of California, Arizona, New Mexico, Nevada, and Texas, and of Central and South Americas.[12] In the United States, the southern San Joaquin Valley and southern Arizona have the highest endemicity.[13] Infection in endemic areas is the result of inhalation of spores following soil disruption. Coccidioidomycosis can be a severe illness and result in disability due to pulmonary involvement and disseminated disease; however, most infections are asymptomatic. Influenza-like illness is the most common clinical presentation. Infection generally imparts immunity to reinfection, although rare cases of reinfection have been reported.[14–17]

State and local health departments involved in investigating previous outbreaks of coccidioidomycosis at endemic sites, and the National Institute for Occupational Safety and Health (NIOSH) guidance document regarding control of airborne fungal infectious agents such as *Histoplasma capsulatum* spores,[2,18] recommend wearing a NIOSH-approved, fit-tested respirator at least as protective as a half-mask respirator with a NIOSH-certified N95 particulate filter when engaged in soil-disturbing activities in endemic areas. Nevertheless, consistent state and federal standards for preventing occupational coccidioidomycosis, including respirator use guidelines, are lacking. Although California's recently enacted Aerosol Transmissible Diseases Standard is the first regulation designed to protect workers from aerosol-transmitted infectious diseases in the workplace, it does not apply to *Coccidioides* outside the laboratory setting.[19]

Despite a considerable volume of literature documenting coccidioidomycosis as an occupational risk, outbreaks continue to occur among workers. In November 2007, the San Luis Obispo County Health Department requested the assistance of the California Department of Public Health (CDPH) in evaluating a suspected cluster of coccidioidal pneumonia in a construction crew at the Camp Roberts military base. This National Guard training site is located on the border of San Luis Obispo and Monterey counties. CDPH jointly investigated the cluster with county staff, evaluated factors that contributed to disease, and made recommendations to prevent future occupational exposures at this worksite. The epidemic curve, descriptive epidemiology, clinical aspects, and laboratory data from this investigation have been described and are consistent with the disease due to a single-point-source exposure that occurred at the Camp Roberts construction site.[20] In this article, we describe the occupational aspects of the investigation, present an analysis of statewide claims for occupational coccidioidomycosis, and discuss recommendations for protection of workers, including risk-based respirator-selection decisions.

METHODS

Worksite Investigation

CDPH industrial hygiene, epidemiology, and medical staff visited the construction site, interviewed workers, and reviewed medical records. During the site visit, staff observed work practices, including personal protective equipment used, and interviewed personnel at the military base. Workers were interviewed over the telephone; the survey instrument utilized for the construction crew included work activities and protective measures used at the outbreak worksite.[20] Demographic characteristics of this crew, medical history, and signs and symptoms have been described.[20] Dust levels were not measured at the excavation site and distance from the trench was deemed to be an unreliable method of determining the risk of dust exposure as workers did not remain in any single location for the duration of their work.

From the Occupational Health Branch (Drs Das and Materna, and Ms McNary, Ms Fitzsimmons, and Ms Dobraca) and Infectious Diseases Branch (Ms Cummings, and Drs Mohle-Boetani and Wheeler), California Department of Public Health; San Luis Obispo County Health Department (Ms McDowell), Calif; and National Institute for Occupational Safety and Health (Drs Iossifova, Bailey, and Kreiss), Atlanta, Ga.

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Workplace Recommendations

CDPH provided worksite-specific health and safety recommendations and initial respiratory protection recommendations to the involved employers and workers. Immediately after the cases were reported, we recommended that the crew use half-mask particulate respirators when digging in soil at Camp Roberts. *C. immitis* spores are approximately 5 μm in diameter[4] and adhere to soil particles of a wide size range, which are effectively captured by NIOSH-certified respirator filters. When the high attack rate for this outbreak became apparent, we revised our recommendations by applying a risk-based approach to respirator selection.

We used a simplified exponential dose–response relationship to estimate the spore dose received by workers at this pipeline construction site.[21] We assumed it takes one spore to result in *C. immitis* infection: Infection risk $= 1 - \exp(-D)$, where D is the expected dose in the alveolar region.[22–24] The dose D is a product of several factors including the spore concentration in ambient air:

$$D = C \times B \times T \times \text{days} \times f$$

C, average spore concentration in air (no./m^3); B, inhalation rate (m^3/hr); T, number of hours per day; days, number of days exposed; f, spore deposition fraction in alveolar region.

Finally, we utilized the Federal Occupational Safety and Health Administration's assigned protection factors (APFs) for respirators to estimate the reduction in infection risk provided by each type of respirator.[25] We assumed that the use of respirators would reduce the average spore concentration (and thereby dose) by a factor determined by the APF.

Workers' Compensation Data

To assess the statewide burden of occupational coccidioidomycosis, we analyzed data from the Workers' Compensation Information System, an electronic administrative claims database maintained by the California Department of Industrial Relations. A surveillance case definition was developed by which a coccidioidomycosis-related claim was identified if the date of injury was between January 2000 and December 2007, and the claim had an *International Classification of Diseases, 9th edition,* code for coccidioidomycosis (114 to 114.5 and 114.9) and/or had an injury description with key words indicating exposure to *C. immitis*. Occupation was coded according to the Census 2000 Index of Occupations.[26] Industry was coded according to the 2002 North American Industry Classification System and organized into 2002 Census Industrial Classifications using a crosswalk produced by the Bureau of Labor Statistics for the Current Population Survey.[27] Claim rates by industry and occupation were calculated for California workers 16 years and older, using estimates of employed civilian population from the 2003 Current Population Survey (midpoint of the time interval examined).[27] The California mining industry population was not listed by Bureau of Labor Statistics due its small labor force base. An estimate was calculated by multiplying the percent of California workers in the mining industry by the total estimate of the California-employed civilian population as reported in the 2003 Current Population Survey.[27] Claim rates were not calculated for industries with less than five claims filed from 2000 to 2007. For rate estimates, 95% confidence intervals were calculated using Byar approximation.[28] All calculations and statistical analysis were conducted using SAS version 9.1 (SAS, Inc, Cary, NC) or Microsoft Excel 2003 (Microsoft, Redmond, WA).

RESULTS

Workplace Investigation

In October 2007, a civilian construction crew excavated a 1200-ft long trench to replace a water pipe at Camp Roberts, a California National Guard military base owned by the US Army in San Luis Obispo County, California. The original pipe, located 20 to 50 ft from the replacement pipe, had failed in January 2006, leaking its full contents across the hillside to the flatlands below.

Ten of the 12 crew members developed clinical symptoms consistent with acute pulmonary coccidioidomycosis (attack rate 83%).[20] Eight had serologically confirmed disease; seven had abnormalities on chest radiograph; and one developed disseminated disease. One worker, without evidence of clinical infection more than 40 days after the outbreak, was diagnosed with coccidioidomycosis in March 2008, following his return to work at the outbreak site in February 2008. The 10 ill crew members sought care from at least 21 physicians and lost a total of at least 1660 hours of work. One worker was assigned to light duty for 160 hours, and two workers were on disability 5 months after the outbreak was detected, the last time the authors had contact with affected crew members.

The 12-member crew worked four 10-hour days per week with some variations over a 10-day period in the East Garrison of Camp Roberts. The crew consisted of two pipe layers, three laborers, three earth-moving equipment operators (using excavator, backhoe, and skid steer), one water truck operator, one dump truck operator, and two supervisors. During interviews, the crew reported that they all worked in the same location, excavating the trench, installing the pipe, packing the excavated soil back around the pipe, and backfilling the trench. The trench (1200-ft long × 4-ft wide × 2- to 5-ft deep) was excavated mechanically and was compacted and backfilled both mechanically and manually. The soil was wetted with water to decrease airborne dust levels and to ensure proper soil compaction around the pipe. When sand was encountered, the crew began intensive wetting using two hoses; however, the sandy soil mostly repelled the water.

Of eight workers who reported their perception of the dust level on the "dustiest" day, two reported low dust, two reported moderate dust, and four reported high dust levels. While the company had access to at least one excavator with air conditioning, the crew was not using that excavator at the time of the outbreak at this location. In addition, the crew always used equipment with the windows open, thus bypassing any dust filtration that the enclosed cab could have provided. Although N95 filtering facepiece respirators were available, workers were not specifically advised by the employer to wear them at this site, and none did so. None of the workers reported having received training on prevention of coccidioidomycosis and before the outbreak, none were aware of a risk of coccidioidal infection at this worksite

The outbreak site was an exposed, west-facing hillside with extensive rodent burrows and where cattle grazed until 6 months before the outbreak. Area rainfall was twice the 30-year average during the winter of 2004-2005, normal in the winter of 2005-2006, and lower than expected in the winter of 2006-2007. The 600,000 gallons of water that leaked from the water tank onto the outbreak site in January 2006 greatly increased the water present at the site during the winter of 2005-2006. In addition, the rains during the winter of 2005-2006 extended into April and May, which was later in the season than usual.

During the course of investigating this outbreak, the San Luis Obispo County Health Department notified CDPH of a military instructor at Camp Roberts who was also confirmed to have coccidioidomycosis on the basis of symptoms, chest radiography, and serologic testing (Figure 1). The instructor was not associated with the construction crew but did work in the same general geographical region; illness was diagnosed during the same time period as those considered part of this outbreak (December 2007).

Workplace Recommendations

CDPH made several recommendations for minimizing exposure and risk of future infection at this construction site (Table 1). These multiple controls were intended to be used simultaneously,

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On December 19, 2007, a non-smoking Hispanic male National Guard instructor and California resident aged 52 years presented to a military clinic in San Luis Obispo County with a two-week history of headache, fever, cough, shortness of breath, and chest pain and was prescribed Augmentin for presumptive pneumonia. For six months before symptom onset, he had worked on the military base at Camp Roberts training National Guard recruits and preparing terrain for training exercises. His activities included manually removing weeds, digging training holes, and demonstrating maneuvers that involved running or crawling for long distances on the ground without respiratory protection. On January 9, 2008, he presented to an Emergency Department in San Luis Obispo County with worsening symptoms and a 20-pound weight loss. Chest radiography demonstrated consolidation of the right upper lobe and suggested an enlarged right mediastinal lymph node. Coccidioidal serology indicated positive precipitin antibodies and negative complement-fixing antibodies. On January 14, 2008, he was prescribed fluconazole for treatment of coccioidomycosis. Fatigue and dyspnea prevented him from working for six months during which chest radiographs indicated gradual improvement; follow-up serologies were not obtained. He returned to work in July 2008, with residual mild dyspnea on exertion.

FIGURE 1. Clinical details of military instructor diagnosed with coccidioidomycosis at Camp Roberts.

since any single exposure control method would not have been sufficiently protective to minimize exposure and reduce the risk of infection to an acceptable level. These included using high-efficiency particulate air (HEPA) filtered air-conditioned enclosed cabs on heavy equipment and training workers on ways to prevent exposure, such as the proper use of construction equipment, wearing respiratory protection, and controlling dust at the source by continually wetting the soil. Additional recommendations included improving the Injury and Illness Prevention Program, which is mandatory for all California employers, and the medical surveillance program to identify illness prevention strategies, and improve prompt access to medical care for all work-related illnesses and injuries.[29]

Respirator Selection

On the basis of an attack rate for this outbreak of 83%, the expected dose to the alveolar region, D, is calculated as follows:

$$\text{Infection risk} = 1 - \exp(-D)$$
$$0.83 = 1 - \exp(-D)$$
$$\exp(-D) = 0.17$$
$$D = -\ln(0.17) = 1.77 \text{ spore}$$

The risk reduction afforded by two different types of respirators was assessed. The effect of wearing a respirator is to reduce the inhaled concentration, which in turn reduces the expected inhaled dose (D in the risk equation given earlier). Earlier in this article, we showed that the expected dose is a product of the spore concentration in air, the duration of exposure, the volumetric breathing rate of the worker, and the fraction of inhaled spores that deposit in the pulmonary region.

Negative-pressure half-mask air-purifying respirators equipped with N95, N100, or P100 filters have an APF = 10 and would reduce the average spore concentration (C in the equation given earlier) to one tenth of the ambient concentration. Tight-fitting, full-facepiece powered air-purifying respirators (PAPRs) (and some

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TABLE 1. Recommendations Provided by California Department of Public Health to San Luis Obispo County Construction Site Employer to Minimize Dust Exposure and Risk of *Coccidioides* Infection

Type of Control	Principle	Components
Engineering and work practices	Control dust at source or isolate worker from exposure	• Continuous soil wetting • Heavy equipment: HEPA-filtered air-conditioned enclosed cabs with 2-way radios • Wash equipment before movement off-site
Administrative	Increase hazard awareness and knowledge of safe work practices	• Train workers and supervisors: ○ Distribution ○ Symptoms and signs ○ Effective controls, including proper use of equipment
	Implement comprehensive illness prevention program	• Injury and Illness Prevention Plan*
Personal protective equipment and hygiene practices	Prevent inhalation exposure	• Respirators when digging or working near earth-moving machinery: ○ Half-mask or full-face respirator with particulate filter† ○ Powered air-purifying respirator with particulate filter‡ ○ Respirator training, fit-testing, and medical clearance • Lockers, coveralls, and change clothing at worksite
Medical care	Disease recognition and prompt, appropriate treatment	• Contract with local medical clinics ○ Protocol for evaluation, follow-up, and treatment ○ Prompt care • Physician training

*California Code of Regulations, Title 8, Section 3203. Injury and Illness Prevention Program. Available at: http://www.dir.ca.gov/Title8/3203.html.
†Initial recommendation made before completion of investigation.
‡Risk-based recommendation based on attack rate in this incident.

helmet/hood PAPRs) with high-efficiency particulate filters have an APF = 1000 and would reduce the average spore concentration to 1/1000 of the ambient air concentration. This information served as the basis for issuing revised recommendations for the appropriate type of respiratory protection in this endemic area. In a similar high-risk worksite, the use of a PAPR (APF = 1000) with HEPA filters would be estimated to reduce the infection risk to 0.17%, whereas a half-mask air-purifying respirator (APF = 10) with HEPA filters would reduce the risk to 16% (Table 2). As a result, we issued an updated recommendation to wear PAPRs (APF = 1000) equipped with HEPA filters when engaging in soil-disrupting activities at this site.

TABLE 2. Calculated Risk of Coccidioidal Infection Based on Type of Respirator Used

Respirator Type	Assigned Protection Factor	Infection Risk (%)*
Half-Mask Respirator (elastomeric or filtering facepiece N95)	10	16
Powered Air-Purifying Respirator	1000†	0.17

*Risk of infection at construction site with exposure scenario similar to that described in this article.
†Some powered air-purifying respirators (PAPRs) have an assigned protection factor (APF) of 1000; however, some have a lower APF. The wearer must obtain information from the manufacturer about the APF for each specific PAPR they intend to wear. (California Code of Regulations, Note 4 in Title 8, Section 5144, Respiratory Protection, Table 1—Assigned Protection Factors.)

Workers' Compensation Data

During the 8-year period 2000 to 2007, 461 unique coccidioidomycosis claims were identified, and the average annual claim rate was 0.35 per 100,000 workers. Median claimant age was 41 years (range, 18 to 70 years). More than 78% of claimants (n = 360) were male. The largest group of claimants worked in service occupations (n = 133), although the highest claim rates occurred in the occupational categories of farming, fishing, and forestry, and construction and extraction (Table 3). The number and rate of occupational coccidioidomycosis cases nearly quadrupled from 2000 to 2006, but this increase was not sustained in 2007 (Figure 2).

When we categorized workers' compensation data by industry, as opposed to occupation, we obtained slightly different results. From 2000 to 2007, the public administration industry had the highest number of claims due to coccidioidomycosis, whereas the mining, quarrying, and oil and gas extraction industry had far fewer claims but the highest rate (Table 4).

DISCUSSION

The disease outbreak among construction workers described in this article and the analysis of workers' compensation claims data illustrate that, despite known risk factors, occupational coccidioidomycosis remains an important concern in California. The high attack rate at this worksite was most likely a result of general lack of awareness regarding coccidioidomycosis and its endemicity at this site, resulting in inadequate worker training; inability to adequately assess the presence of the organism in soil; rainfall patterns and tank leakage that may have facilitated fungal growth; considerable soil disruption in a geographic area endemic for *C. immitis*; and failure to use appropriate control strategies, including respiratory protection. Recommendations for disease prevention in occupational settings are based on these factors.

In 1942, Shelton[30] reported that coccidioidomycosis could be acquired at Camp Roberts, a "hitherto unknown endemic focus." In 2000, the US Geologic Survey[31] still considered this a "suspected endemic region." Nevertheless, in 2007, neither the National Guard, the lessee of this property, nor the employer of the construction

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TABLE 3. Number of Cases, Percentage,* and Estimated Average Annual Rate† of Coccidioidomycosis-Related Claims Submitted to the Workers' Compensation Insurance System by Occupation Category, California, 2000 to 2007

Occupation Category (COC)	No. (%)	Rate	95% CI
Farming, fishing, and forestry (600–613)	23 (5)	1.24	0.79–1.87
Construction and extraction (620–699)	78 (17)	1.11	0.88–1.38
Service (360–465)	133 (29)	0.64	0.54–0.76
Production, transportation, and material moving (770–975)	46 (10)	0.30	0.22–0.41
Management, professional, and related (001–354)	100 (22)	0.21	0.17–0.26
Installation, maintenance, and repair (700–769)	7 (2)	0.14	0.05–0.30
Sales and office (470–593)	13 (3)	0.04	0.02–0.06
Unknown	61 (13)	–‡	–‡
Total	461 (100)	0.35	0.32–0.39

*Percentages may not add to 100 because of rounding.
†Per 100,000 civilian workers aged 16 years or older with 95% CI; denominator data from Current Population Survey employed civilian population estimates, 2003.
‡Annual rate and 95% CI could not be calculated because denominator data could not be determined for the category.
CI, confidence interval; COC, 2000 Census Occupation Codes.

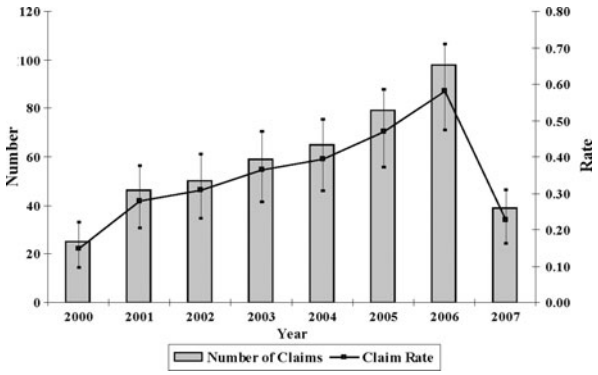

FIGURE 2. Number and estimated rate* of coccidioidomycosis-related workers' compensation claims† by year, California, 2000 to 2007 ($n = 461$). *Per 100,000 civilian workers aged 16 years or older with 95% confidence interval; denominator data from the Current Population Survey employed civilian population estimates. †Data are derived from our analysis of the Workers' Compensation Information System, an electronic administrative claims database maintained by the California Department of Industrial Relations.

crew knew that previous outbreaks had occurred in this region. The diagnosis of coccidioidomycosis in a military instructor at Camp Roberts during the same time period as the outbreak suggests that the risk of the disease was more widespread than at just the construction site and that *Coccidioides* species may have been sporadically present throughout the entire military base.

California regulation requires employers to establish worksite- and hazard-specific Illness and Injury Prevention Plans.[29] Because the endemicity of *Coccidioides* species at Camp Roberts was unrecognized, workers were not provided with training about the risk of disease at this worksite or of work practices to reduce the probability of its occurrence. From 2000 to 2007, surveillance data showed that the rate of coccidioidomycosis in San Luis Obispo County was in the highest quintile of the state, 14.5 to 150.0 cases per 100,000 population.[32] This supports the assertion that *C. immitis* should be considered endemic to this area and that education on the etiology and prevention of the disease should be disseminated to employers, workers, and communities.

Coccidioidomycosis is on the list of National Notifiable Diseases, although not all states have made it reportable.[33] Arizona and California are among the states where coccidioidomycosis is a reportable condition. From 1997 to 2007, the incidence rate increased 281% in Arizona.[13] In California, the numbers of cases and the incidence rate more than tripled from 2000 to 2006.[32] Reported coccidioidomycosis cases in California increased from 816 in 2000 (incidence rate, 2.4 per 100,000 population) to 2981 in 2006 (8.0 per 100,000 population). Postulated factors accounting for rising disease incidence include climate change; migration patterns, including movement of susceptible populations to endemic areas; and new construction in endemic areas.[13,34]

Our finding of the near quadrupling of coccidioidomycosis incidence in California workers' compensation claims from 2000 to 2006 reflects trends in the general population and among military personnel in California for the same time period.[5,32] The significance of the decreased incidence in 2007, in both the general population and among workers, is unknown at this time. The highest rates of coccidioidomycosis were observed among agricultural and construction workers, who are likely to have the greatest dust exposure, and in the mining industry, which involves considerable soil disruption. The high numbers of cases observed in public administration may have been due to the inclusion of the public safety industry, which in California has experienced several recent large outbreaks of coccidioidomycosis in prisons.[35–37] The distribution of coccidioidomycosis among occupational groups is consistent with historical reports of the highest disease rates among construction and agricultural workers in California.[4]

Although the overall pattern of coccidioidomycosis incidence obtained from our analysis of workers' compensation claims reflects population trends, both the overall numbers and the rates among workers are much lower than those in the general population for the same time period. This is most likely because the disease is not recognized as work-related except in outbreak situations; it is also possible that work-related coccidioidomycosis is underreported by workers and/or physicians, or that occupational exposure accounts for a small proportion of cases.

Our examination of workers' compensation data showed that occupational incidence rates decreased in 2007, the year this outbreak occurred. Local issues and weather patterns may have played a role in this outbreak. *C. immitis* thrives during wet periods after droughts, and disease incidence is correlated with rainfall in recent previous seasons.[38,39] Heavy rainfall 2 years before this outbreak and leakage of the water tank at the site during the previous winter may have contributed to fungal growth. Interestingly, Zender and Talamantes[40] found that precipitation and other weather patterns (such as wind) explain a much smaller proportion of coccidioidomycosis incidence in California (4%) compared with Arizona (75%). These authors have therefore suggested that human soil-disrupting activity, such as digging in endemic areas, is the most important determinant of coccidioidomycosis incidence in California. Nevertheless, soil sampling is unreliable for predicting the presence of *C. immitis* spores. Even in endemic areas, spores are unevenly distributed, and false-negative results may lead to an inappropriate

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TABLE 4. Number of Cases, Percentage,* and Estimated Average Annual Rate† of Coccidioidomycosis-Related Claims Submitted to the Workers' Compensation Insurance System by Industry Category, California, 2000 to 2007

Industry Category (CIC/NAICS)	No. (%)	Rate	95% CI
Mining, quarrying, and oil and gas extraction (0370-0490/ 21)	9 (2)	6.91	3.15–13.12
Public administration (9370-9590/ 92)	181 (39)	3.07	2.64–3.56
Agriculture, Forestry, Fishing, and Hunting (0170-0290/ 11)	25 (5)	1.00	0.65–1.48
Construction (0770/ 23)	67 (15)	0.75	0.58–0.95
Transportation and utilities (0570-0690, 6070-6390/ 22, 48-49)	26 (6)	0.45	0.29–0.65
Professional and business services (7270-7490, 7570-7790/ 54, 55-56)	31 (7)	0.20	0.13–0.28
Education and health services (7860-8470/ 61-62)	45 (10)	0.18	0.13–0.24
Manufacturing (1070-3990/ 31-33)	14 (3)	0.09	0.05–0.15
Other industries‡	13 (3)	–§	–§
Unknown	50 (11)	–§	–§
Total	461 (100)	0.35	0.32–0.39

*Percentages may not add to 100 because of rounding.

†Per 100,000 civilian workers aged 16 years or older with 95% CI; denominator data from Current Population Survey employed experienced civilian population estimates, 2003.

‡All major CIC industry categories had claims, but major industries with less than five claims were excluded from rate analysis.

§Annual rate and 95% CI could not be calculated because denominator data could not be determined for the category.

CI, confidence interval; CIC, 2002 Census Industrial Classification; NAICS, 2002 North American Industry Classification System.

sense of security. Moreover, the assay method is expensive, time-consuming, and not available commercially.[3,12,41,42]

The excavation and replacement of the damaged water line at this National Guard training site involved considerable soil disruption. The crew's attempts to control dust through wetting were inadequate because the sandy soil failed to absorb water. Occupational risk factors, such as job title and duties, were not associated with disease risk or severity.[20]

In spite of the inability to quantify exposure, the high attack rate reflects that workers had a sufficient dose of *C. immitis* spores over the course of their work at the site to cause clinical illness. Similarly, high attack rates have been reported in previous occupational outbreaks involving soil-disrupting activities.[43–45] The high attack rate is in part due to several properties exhibited by *C. immitis* spores: easy dispersion, respirability, and infectivity. Spores are 2 to 5 μm in diameter and are able to reach terminal bronchioles and alveoli.[4,46] In animals, 10 spores are sufficient to cause infection.[46] It has been suggested that human illness could be caused by a single spore.[22]

The high attack rate and low human infectious dose were important considerations in developing respiratory protection recommendations for this worksite. Use of PAPRs with an APF of 1000 and HEPA filters would reduce the calculated risk of infection to 0.17%; half-mask respirators equipped with filters would result in an unacceptably high risk of 16%. Since the pattern of distribution of *C. immitis* is unpredictable, it is prudent to expect that spores may be present in soil throughout the Camp Roberts site. Consequently, CDPH recommended workers at Camp Roberts (including military personnel) wear PAPRs with HEPA filters anywhere on the site when manually digging in soil or working in dusty conditions unless in an enclosed cab with HEPA air filtration.

A PAPR, available with a loose-fitting hood, helmet, or tight-fitting, full facepiece, also provides eye protection in dusty work and is more comfortable than half-mask respirators for breathing, communication, and temperature and humidity inside the facepiece. These features might increase worker compliance with respirator use in dusty construction settings.[47] Nevertheless, since personal protective equipment is the least effective measure in reducing exposure to hazards, and since there are many potential barriers to respirator use in construction, CDPH recommended that a respiratory protection program at this worksite be part of a multifaceted approach to reducing the risk of coccidioidomycosis.[48] These include engineering, work practice, administrative controls, and medical care (Table 1).

Engineering and work practice controls consist of dust-suppression measures during construction in endemic areas: continuous soil wetting, avoiding outdoor construction during unusually windy conditions, and using enclosed heavy equipment cabs with HEPA filtered air-conditioning.[4,31] During the incident at Camp Roberts, soil wetting was attempted but was ineffective in controlling dust, demonstrating that any single measure may be inadequate to control exposure to *Coccidioides* spores. Because occupational coccidioidomycosis has been attributed to airborne exposure to spores contained in resuspended dust, equipment and vehicles should be cleaned before transport off-site, and clothing and shoes should be removed before leaving the worksite.[3] Administrative controls include development and adherence to an injury and illness prevention program that acknowledges hazards and implements mitigation methods, including provision of worker and employer training. When working in endemic areas, workforces should receive annual training about coccidioidomycosis symptoms, high-risk activities, dust-control methods, and respiratory protection. Finally, ensuring prompt access to medical care is essential. Because of the public health impact of coccidioidomycosis and because local health care providers vary in their knowledge of this disease, public health authorities should support programs to educate providers on its recognition, diagnosis, management, and prevention in workers. To date, therapeutic options remain limited and, despite considerable research, a preventive vaccine is not available.[49] Health care providers in endemic areas should consider coccidioidomycosis in the differential diagnosis of influenza-like symptoms, particularly in persons with soil-disturbing occupations or persons who have moved or traveled to endemic areas.

There are several historical recommendations for reducing the risk of infection due to *C. immitis* spores during soil-disrupting activities, including spraying the ground with oil.[4,50] But there is insufficient evidence demonstrating that this latter method is effective; moreover, potential adverse effects on human health and the environment are unknown. Skin testing has also been proposed as a method to allow only workers with evidence of previous infection access to endemic areas.[4] Nevertheless, there is currently no commercially available skin test for past coccidioidal infection. Finally, restricting the work force to "resident labor" has been recommended as a screening method to reduce occupational infection. This proposal was based on the presumption that residents of endemic areas were more likely to have had subclinical infection and therefore be immune to reinfection. In the outbreak described in this article, many workers were from endemic areas, but nonetheless developed coccidioidomycosis, suggesting that workers from endemic areas are not necessarily immune and remain at risk for being infected.[20]

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Occupational coccidioidomycosis remains an important concern in some parts of the United States. Infection risk is highest in workers engaging in soil-disrupting activities such as construction and agriculture. A multitude of controls should be utilized to reduce exposure to dust-containing spores of soil-dwelling *Coccidioides* species. In addition to engineering, work practice, and administrative controls, quantitative risk-based calculations provide a framework for making informed decisions for selecting respiratory protection. We have used these calculations to demonstrate that the use of PAPRs (APF = 1000) with HEPA filters at the site of this outbreak would likely reduce the infection risk to a level that is more acceptable than that associated with half-mask elastomeric or filtering facepiece respirators with N95, N100, or P100 filters. Occupational coccidioidomycosis may be better controlled in endemic areas by implementing the multifaceted measures described in this article.

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Climate Factors Influencing Coccidioidomycosis Seasonality and Outbreaks

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Although broad links between climatic factors and coccidioidomycosis have been established, the identification of simple and robust relationships linking climatic controls to seasonal timing and outbreaks of the disease has remained elusive. Using an adaptive data-oriented method for estimating date of exposure, in this article I analyze hypotheses linking climate and dust to fungal growth and dispersion, and evaluate their respective roles for Pima County, Arizona. Results confirm a strong bimodal disease seasonality that was suspected but not previously seen in reported data. Dispersion-related conditions are important predictors of coccidioidomycosis incidence during fall, winter, and the arid foresummer. However, precipitation during the normally arid foresummer 1.5–2 years before the season of exposure is the dominant predictor of the disease in all seasons, accounting for half of the overall variance. Cross-validated models combining antecedent and concurrent conditions explain 80% of the variance in coccidioidomycosis incidence. ***Key words:*** **climate, *Coccidioides*, coccidioidomycosis, environment, meteorologic factors, rain, seasonal variation, southwestern United States, weather.** ***Environ Health Perspect*** **113:688–692 (2005). doi:10.1289/ehp.7786 available via *http://dx.doi.org/* [Online 3 March 2005]**

Coccidioidomycosis, or valley fever, is caused by inhalation of spores from *Coccidioides immitis* and *Coccidioides posadasii*. These dimorphic soil fungi are endemic to the deserts of the southwestern United States, Mexico, and elsewhere in Central and South America (Fisher et al. 2002; Kolivras et al. 2001). Although approximately 60% of people infected with the disease are asymptomatic, others experience mild influenza-like symptoms, and a small percentage experience severe effects and sometimes death resulting from dissemination of the disease to other parts of the body (Kolivras et al. 2001). Those at greatest risk for coccidioidomycosis infection include immunocompromised patients, young children, the elderly, and members of several ethnic minorities in the United States (Kolivras et al. 2001; Pappagianis 1988). In Arizona alone, > 2,000 cases per year have been reported (Komatsu et al. 2003), and the incidence of coccidioidomycosis is greater than that for other emerging infectious diseases in the region such as West Nile virus [Centers for Disease Control and Prevention (CDC) 2004a]. The number of Arizona cases is likely to exceed 3,000 by the end of 2004 (CDC 2004b).

Environmental conditions appear to have an important impact on coccidioidomycosis incidence. The current Arizona coccidioidomycosis epidemic has been linked to climate conditions (Kolivras and Comrie 2003; Komatsu et al. 2003; Park et al. 2005), whereas California experienced an epidemic in the 1990s that was possibly linked to drought conditions (Jinadu 1995). Initial links between climate conditions and the disease were identified several decades ago (Hugenholtz 1957; Maddy 1965). It is only recently that further details on climate and coccidioidomycosis have been published (Kolivras and Comrie 2003; Komatsu et al. 2003). These studies identified associations linking climate and other factors to seasonal patterns of coccidioidomycosis and to interannual variability and trends in the disease. Significant variables included drought indices, lagged precipitation, temperature, wind speed, and dust during the preceding 1 or more years. The relationships to coccidioidomycosis were quite complex, however, perhaps because of disease data issues outlined below. In this article I aim to identify simple and robust relationships linking climatic controls to seasonal timing and outbreaks of the disease, which until now have remained elusive and poorly understood. Important public health opportunities exist if environmental factors controlling coccidioidomycosis outbreaks and trends can be better comprehended, including the timing and degree of mitigation efforts such as soil treatment and the development of an advance warning system for public health management.

Part of the reason for the current state of knowledge has been the lack of high-quality disease data series. In fact, a major challenge to understanding more about the links between climate and infectious disease continues to be the difficulty in obtaining regular time series of disease data (National Research Council 2001). This is especially true for coccidioidomycosis with respect to data on *Coccidioides* in the soil or atmosphere. The current environmental detection method using laboratory mice is expensive and time-consuming, and although there is ongoing research into more rapid detection techniques (e.g., using polymerase chain reaction analysis to detect the fungus in soil samples), it will be several years before time series of such data become available. In the absence of suitable data on the environmental variability of the fungus itself, there is a need to exploit epidemiologic data in different ways to better identify the role of environmental controlling factors such as climate. Thus, for now, disease incidence data offer the best (and only) available multiyear time series for comparison with climatic conditions.

The use of human disease data to study potential relationships to climate conditions introduces numerous methodologic and analytical issues related to collection and reporting. Incidence data do not provide a homogeneous time series because of changes in reporting requirements, changes in population demographics, and the introduction of new diagnostic tests. In addition, the reported data necessarily contain imprecise estimations of disease onset dates because of various factors including patient recall, incorrect or delayed diagnoses caused by displacement of diagnoses during the respiratory disease season, and the variability in disease incubation and onset of symptoms from case to case.

If these data issues can be dealt with at least partially, the research challenge in using human incidence data is to understand the second- or third-order connections between the soil fungus and reported cases of the disease. There are essentially two hypothesized parts to the role of climate (Kolivras and Comrie 2003) that need to be evaluated. First, existing *Coccidioides* spores present in dry soil need increased soil moisture (via precipitation) to grow the fungus, followed by a dry period during which fungal hyphae desiccate and form spores. Second, wind or other disturbance is required to disperse the spores for inhalation by a host. The relative roles of these climate factors in the seasonality and outbreaks of coccidioidomycosis are not clearly understood. My principal goals in this article are therefore to analyze the postulated climate and dust relationships to fungal

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growth and dispersion and evaluate their respective roles.

Two subquestions are also considered. First, southern Arizona has a bimodal annual precipitation pattern with one peak in summer and one in winter (Sheppard et al. 2002), but county-level coccidioidomycosis reports in the past have not clearly reflected an associated bimodal coccidioidomycosis pattern (Kolivras and Comrie 2003). Yet early work and a study using student health service data have noted such a pattern (Hugenholtz 1957; Kerrick et al. 1985). Thus, in this article I examine whether recent county-level reports can shed light on the existence of a bimodal incidence pattern in reported data. Second, in evaluating climatic controls on coccidioidomycosis, the critical date is the date of exposure (spore inhalation) rather than the case report date. A method is required that incorporates this lag as well as the changes in coccidioidomycosis reporting characteristics over time. This article presents such an adaptive data-oriented method for estimating date of exposure.

Materials and Methods

Tucson and the surrounding areas of Pima County in Arizona are highly endemic for coccidioidomycosis (Kolivras et al. 2001). Pima County coccidioidomycosis case data were obtained from the Arizona Department of Health Services (Phoenix, Arizona) for the period 1992–2003. Reporting was voluntary at the beginning of this period (Ampel et al. 1998), although the data continuity and quality are good relative to previous decades (Kolivras and Comrie 2003). The disease became nationally notifiable in 1995 and reporting by laboratories became mandatory at the state level in 1997 (Komatsu et al. 2003). Although the number of reported cases initially appeared to increase as a result, this effect appears to have been minor because incidence continued to grow in an ongoing epidemic (Komatsu et al. 2003).

Pima County annual mid-year population data were obtained from the U.S. Census Bureau (2004). Environmental data were obtained for the greater Tucson urban area, which contains > 90% of the county population. Both precipitation and dust are good potential predictors of coccidioidomycosis (Kolivras and Comrie 2003; Komatsu et al. 2003). Monthly precipitation data for all five available sites in the Tucson area were obtained from the Western Regional Climate Center (2004) for 1988–2003. In conjunction with the incidence data, the precipitation data enable evaluation of hypothesized soil-moisture–fungal-growth relationships. Ambient concentrations of atmospheric particulate matter with a diameter < 10 µm (PM_{10}) were obtained from the Pima County Department of Environmental Quality (2004) for the five stations with data from 1991–2003. The PM_{10} data are a direct measure of airborne dust, and because this size threshold includes the typical spore size, these data should be proportionally related to the hypothesized windblown spore concentrations. Precipitation and PM_{10} values were averaged across sites to provide a single time series of the areawide mean for each.

With regard to analyzing the hypothesized climatic controls on coccidioidomycosis, the most relevant information to extract from the incidence data is the date that each patient most likely inhaled the fungal spore (i.e., exposure date). The coccidioidomycosis incidence data include three possibly useful dates to approximate exposure date: estimated date of onset of symptoms ("onset date"), diagnosis date, and report date (although many cases do not have all three dates recorded). Onset date is potentially the most useful of the three, but it is only available for about one-third of the cases, and that proportion varies considerably over time. Ideally, the onset date accounts for some of the variable lag between exposure and reporting; although it is imprecise, it is likely the most accurate index of exposure date. Conversely, the diagnosis date is more precise but the exposure-to-diagnosis lag, which varies from case to case and is longer than the exposure-to-onset lag, has to be estimated in some way. Diagnosis dates are available for most cases. Report dates are, de facto, available for all cases, but they are the most lagged in time from the exposure date; exposure-to-report lags therefore display the greatest variability and are least likely to provide useful links to climate.

Exploration of the various lags and dates indicated no consistent bias or pattern that could be satisfactorily corrected via simple adjustments, such as an overall mean onset-to-diagnosis delay. Instead, the mean onset-to-diagnosis and onset-to-report lag times were calculated for each individual month in the record (rather than averaged across the entire time series). These temporally adaptive empirical lags were smoothed with a 3-month moving average, centered on the middle month, and then used to estimate exposure dates. For cases with an onset date, the exposure date was estimated to be 14 days earlier to allow for the incubation period (Kolivras and Comrie 2003); for cases without an onset date but with a diagnosis date, the exposure date was estimated to occur earlier by the number of days for that month-specific onset-to-diagnosis lag plus 14 days; for cases with only a report date, the exposure date was estimated to occur earlier by the number of days for that month-specific onset-to-report lag plus 14 days. For example, a case reported on 24 November 2003 might have a diagnosis date of 24 July 2003 and no onset date. Based on the mean of other reports with onset dates in November 2003 (actually the October through December 2003 mean), the onset–diagnosis lag is 10 days, so this case would be estimated to have had an onset date of July 14, and thus an estimated exposure 14 days before, on 30 June.

There were 3,283 cases in the data set; 3,181 of these had diagnosis dates, but only 1,089 had onset dates. The proportion of the latter each month and the length of lag for either varied inconsistently over time, necessitating this set of temporally adaptive adjustments. Onset–diagnosis lags had a mean of 12.6, a median of 11.5, a standard deviation of 5.9, a minimum of 2, and a maximum of 32 days; onset–report lags had respective values of 43.0, 44.0, 19.1, 8, and 99 days. Monthly case totals based on estimated exposure were computed and converted to incidence rates per 100,000 of population using linearly interpolated monthly population estimates.

To analyze the lagged relationships and the relative climatologic significance of different times of year, the data were grouped into seasons. Seasonal analyses are advantageous for several reasons: *a*) they are a useful way of dividing the year into alternating wet and dry periods, *b*) they facilitate identification of recurring times of the year that are important, *c*) seasonal aggregation avoids the monthly variability that characterizes the region and leads to overly complex analyses, and *d*) it is analytically and conceptually simpler to compute and understand seasonal lag relationships. In the southwestern United States, seasons are defined principally by precipitation rather than the thermally based spring, summer, fall, and winter sequence typical of middle-latitude locations (Sheppard et al. 2002). Seasonal groupings are widely used for similar kinds of climate analyses (Crimmins and Comrie 2004). Seasons were defined by monthly sequences that captured the predominant seasonal maxima and minima for each variable.

Stepwise regression of the 1992–2003 seasonal data was used to model coccidioidomycosis rates from concurrent PM_{10} (hypothetically related to spore dispersion and therefore exposure) and concurrent and lagged antecedent precipitation (hypothetically related to fungal growth). Previous work has shown that the relevant climate conditions may be different for each coccidioidomycosis season (Kolivras and Comrie 2003), and therefore each season was modeled separately. Models were cross-validated on independent data points using a leave-one-out jackknife method. Because coccidioidomycosis reporting before 1997 may not have been consistent, the same modeling analysis was run on a subset of the data covering just the improved reporting period from 1997 through 2003 for confirmatory purposes.

Results

Application of the estimated exposure date methodology resulted in a time series of

coccidioidomycosis incidence, as defined above. An annual plot shows the epidemic in recent years, which coincides with an ongoing regional drought as well as variability in PM_{10} (Figure 1). The 2003 decrease may end up being less pronounced after some reports recorded later in 2004 (unavailable at the time these study data were acquired) are estimated to have been 2003 exposures. Analysis of similar data for the Phoenix area attributed the increase in coccidioidomycosis to climate-related factors (Komatsu et al. 2003).

Average monthly coccidioidomycosis rates based on estimated exposure dates display obvious seasonal behavior (Figure 2), but with greater clarity than in previous studies. A bimodal pattern with peaks in June–July and October–November is apparent, along with relatively lower incidence in August–September and February–March. PM_{10} concentrations follow an inverse relationship with soil moisture, falling during wet periods and rising during dry periods (Figure 2). Monthly coccidioidomycosis rates are largely consistent with the hypothesis of increased dust exposure leading to increased disease incidence. On the average at least, the less dusty months of the year coincide with lower coccidioidomycosis exposure rates, and elevated rates coincide with or follow the dustier months. Although it is tempting to draw a similar first-order inverse connection between precipitation and incidence at the overall mean monthly level, it is important to recall that this is likely valid for the immediate dust-inhibiting role of rainfall (precipitation has a strong negative correlation with dust) but not likely for its antecedent fungal growth and desiccation role. Thus, although a wet–dry precipitation sequence occurs during the several months before each of the annual coccidioidomycosis peaks on average, closer examination shows that the amount of precipitation and the matching responses as well as the time lags for each are inconsistent. This underlines the importance of investigating the role of antecedent moisture at time scales longer than a season or year.

The monthly averages presented in Figure 2 enabled the definition of seasonal groupings centered on the periods of maxima and minima. Coccidioidomycosis seasons for estimated exposure dates consist of a winter decrease that occurs January through April, a foresummer peak that is seen May through July, a monsoon decrease that takes place in August and September, and a fall peak that is experienced October through December. The same seasons were used for monthly PM_{10} concentrations because they had similar periods of maxima and minima, and because they needed to match the coccidioidomycosis seasons for analysis. For precipitation, the winter peak occurs between December and March, followed by the driest time of the year during the arid foresummer from April through June. The monsoon is the most distinctive aspect of the region's climate, bringing rainfall during July, August, and September, after which conditions become dryer in a brief fall during October and November (Crimmins and Comrie 2004). Because precipitation is hypothesized to affect fungal growth months or years before the exposure date, it is not necessary to have precipitation seasons exactly match the monthly groupings for the other variables. Thus, for example, it is more meaningful to use July through September for monsoon precipitation and relate that seasonal peak to coccidioidomycosis in subsequent seasons. For simplicity, the names of the seasons are kept the same across all variables.

Adjusted R^2 values for the four seasonal models and standardized (β) coefficients for the variables found to be significant in each model are shown in Table 1. All four models explained significantly high to very high proportions of the variance in coccidioidomycosis rates. It is notable that the strongest relationships do not occur simply in a wet–dry sequence in the season immediately before a rise in coccidioidomycosis rates. A remarkable result is the positive role of precipitation during the arid

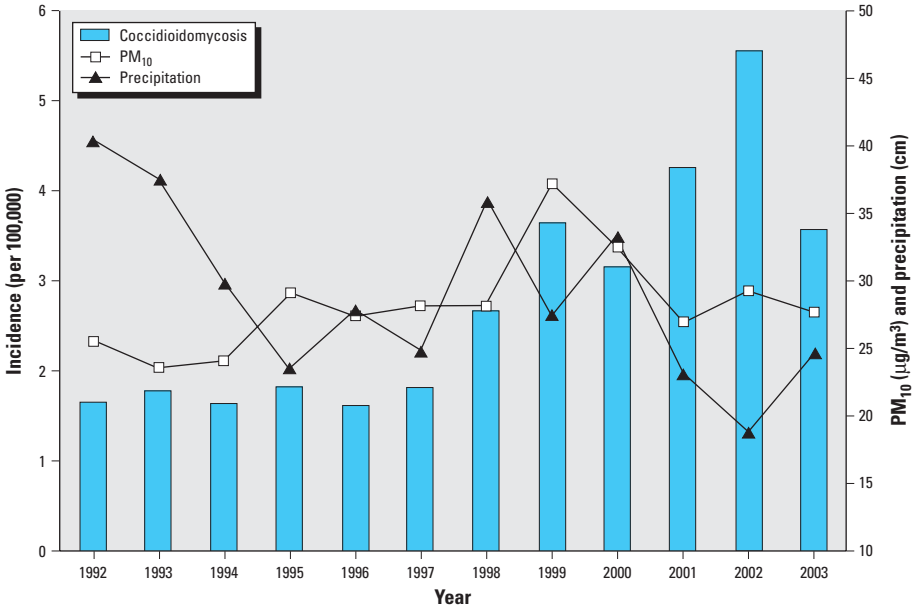

Figure 1. Annual coccidioidomycosis incidence based on estimated exposure date for Pima County, Arizona, with total annual precipitation and mean annual PM_{10} concentrations across sites in the Tucson region.

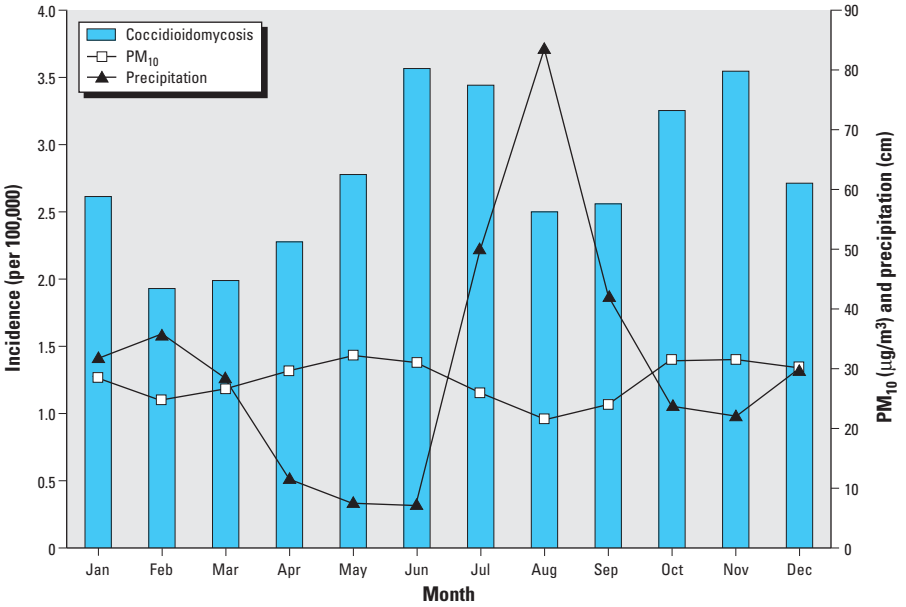

Figure 2. Mean monthly coccidioidomycosis incidence in Pima County, Arizona, based on estimated exposure date, with mean monthly precipitation and mean monthly PM_{10} concentrations, 1992–2003.

foresummer for coccidioidomycosis occurring in all subsequent seasons up to 2 years later. One implication is that precipitation during this hottest and driest part of the year (April through June), as opposed to other wetter seasons, is most favorable for *Coccidioides* growth in the environment. This is typically a time of soil desiccation and vegetation dormancy, so the ability to grow opportunistically in the foresummer may be a competitive advantage of *Coccidioides* over other soil biota. A second implication is that fungal spores produced after a wet period in the foresummer may accumulate in the soil and remain viable for several years. Consistent with this hypothesis, monsoonal precipitation does not appear in any model within a 3-year lag, and in only one at 4 years.

Table 1. Model performance and standardized (β) coefficients for the four seasonal regression models predicting coccidioidomycosis rates from concurrent PM_{10} and antecedent precipitation, 1992–2003 (significance in parentheses).

Measure	Foresummer	Monsoon	Fall	Winter
Performance				
Adjusted R^2	0.98 (≤0.001)	0.60 (0.006)	0.61 (0.006)	0.95 (≤0.001)
Cross-validated R^2	0.95 (≤0.001)	0.66 (0.001)	0.66 (0.001)	0.74 (≤0.001)
Dust				
PM_{10}	0.75 (≤0.001)			0.44 (≤0.001)
Precipitation[a]				
Winter-0	N/A[b]	N/A	N/A	
Fall-0	N/A	N/A	–0.49* (0.029)	–0.36 (0.004)
Monsoon-0	N/A			
Foresummer-0	0.47 (≤0.001)			0.49 (≤0.001)
Winter-1	0.20 (0.023)			–0.33 (0.004)
Fall-1	–0.26 (0.030)			
Monsoon-1				
Foresummer-1		0.45 (0.044)	0.73* (0.004)	0.56* (≤0.001)
Winter-2				
Fall-2				
Monsoon-2				
Foresummer-2	1.36* (≤0.001)	0.64* (0.008)		
Winter-3				
Fall-3				
Monsoon-3				
Foresummer-3				
Winter-4				
Fall-4				N/A
Monsoon-4	–0.93 (≤0.001)		N/A	N/A
Foresummer-4		N/A	N/A	N/A

[a]For precipitation variables, Fall-0 denotes the concurrent fall, Winter-4 denotes the winter occurring 4 years earlier, and so on, ordered from most to least recent. [b]Seasons falling before or after the period including the concurrent season through 4 years earlier are marked as not applicable (N/A). *Model variables that were also present in a 1997–2003 subset analysis, signifying those variables that were significant in both the full-period and the later-period models.

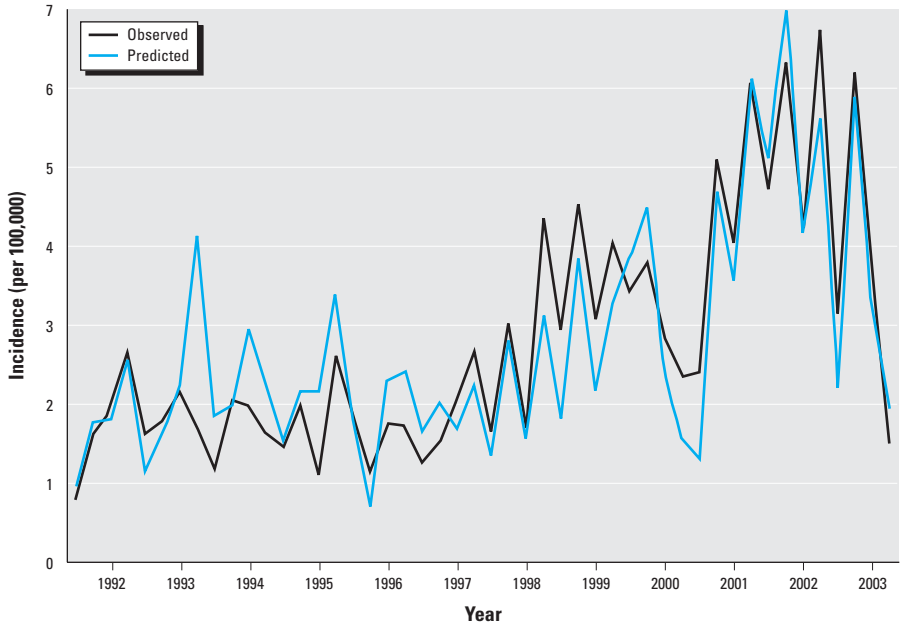

Figure 3. Observed coccidioidomycosis incidence in Pima County, Arizona, and predicted incidence from the cross-validated seasonal models, based on estimated exposure date.

Ambient dust levels, as an index of potential spore dispersion, are positively associated with concurrent coccidioidomycosis rates in winter and the foresummer. Dust is not a useful predictor of coccidioidomycosis rates during the monsoon or the fall. Yet wetter conditions in fall appear to decrease concurrent coccidioidomycosis rates and in the winter immediately after, presumably via dispersion inhibition due to greater soil moisture.

The analysis was repeated on the more reliable 1997–2003 data period to check for consistency. This step reduced the modeled n from 12 to 7, which decreased statistical reliability, and therefore detailed results are not shown. Nonetheless, although the full set of significant variables differed for each model, the results from the shorter period showed some similarities with the longer period. Those variables that were significant in both the full-period and the later-period models are noted by asterisks in Table 1. Both sets of models have in common the foresummer precipitation 1 or 2 years before the predicted coccidioidomycosis season, as well as concurrent fall precipitation for fall coccidioidomycosis incidence.

The overall time series of observed and predicted seasonal coccidioidomycosis incidence (for the full period) is shown in Figure 3. The combined predictions of all four multivariate seasonal models are in close agreement with observations, with an overall cross-validated R^2 of 0.80, and a cross-validated mean absolute error of 0.53 cases per 100,000, or about 19% of the mean incidence. The proportions of model-oriented (systematic) error versus data-oriented (unsystematic) error were 14 and 86%, respectively (Comrie 1997), implying that the model is well specified and that noisy data are responsible for most of the error. To further isolate the role of the foresummer, antecedent foresummer precipitation alone was regressed on coccidioidomycosis incidence in fall, winter, foresummer, and the monsoon in the relevant period 1.5–2 years later. The resulting cross-validated R^2 between observations and combined predictions of all four antecedent foresummer-based models was 0.27.

Discussion

The development of a method to estimate *Coccidioides* spore exposure date from coccidioidomycosis incidence data has enabled the production of a relatively homogeneous time series. This approach reveals a strong bimodal seasonality of the disease in Pima County, Arizona, consistent with earlier findings based on other data (Hugenholtz 1957; Kerrick et al. 1985), a pattern that until now was not clearly seen in the regular reported data. On average,

peaks in exposure to the fungal spores occur in June–July and in October–November, consistent with the drier and dustier months of the year. Fewer exposures occur in February–March and August–September, consistent with the timing of the wetter and less dusty months.

Multivariate models of the incidence data series indicate that concurrent dispersion conditions are important during fall (via precipitation) and in winter and the arid foresummer (via PM_{10}). However, the most striking result of this study is the dominant role of precipitation during the normally arid foresummer 1.5–2 years before the season of exposure. Even when considered alone, April–June precipitation accounts for more than one-quarter of the overall variance in subsequent seasonal coccidioidomycosis incidence. When other antecedent and concurrent seasonal conditions are included as predictors, the combined seasonal models explain a significant and large proportion of the variance in coccidioidomycosis incidence. The model is relatively simple in structure compared with other studies (Kolivras and Comrie 2003; Komatsu et al. 2003). The model uses only lagged seasonal precipitation and concurrent seasonal dust and precipitation, yet it clearly captures both the seasonality and the trends in the incidence data. The bulk of the error is associated with noise in the data, so future improvements to the model are likely to result from improved data and a longer length of record with a larger model *n*.

An improved understanding of the climatic factors behind outbreaks of coccidioidomycosis will enable better timing of environmental sampling for *Coccidioides* and any related mitigation efforts, separation of environmental factors from population and other factors affecting outbreaks, and the potential for development of an advance warning system before an outbreak. The results of this work provide strong support for the two hypothesized relationships between climate and coccidioidomycosis, namely, fungal growth in the longer term and spore dispersion and exposure in the short term. Furthermore, the relative simplicity and strength of these results relative to earlier studies (Kolivras and Comrie 2003; Komatsu et al. 2003) lend considerable confidence to the potential for the development of an operational disease forecast model. The ability to define a critical event, such as precipitation during the foresummer, might enable mitigation procedures immediately after the event as well as provide a useful public health tool with an 18-month lead time on expected incidence of coccidioidomycosis. Future work will need to evaluate how specific these findings are to southern Arizona versus other regions in which *C. posadasii* is also endemic, and whether similar relationships also apply to *C. immitis* in California. It will also be valuable to test how a more complex model (Komatsu et al. 2003) and this simpler model compare against data from other locations and over time.

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