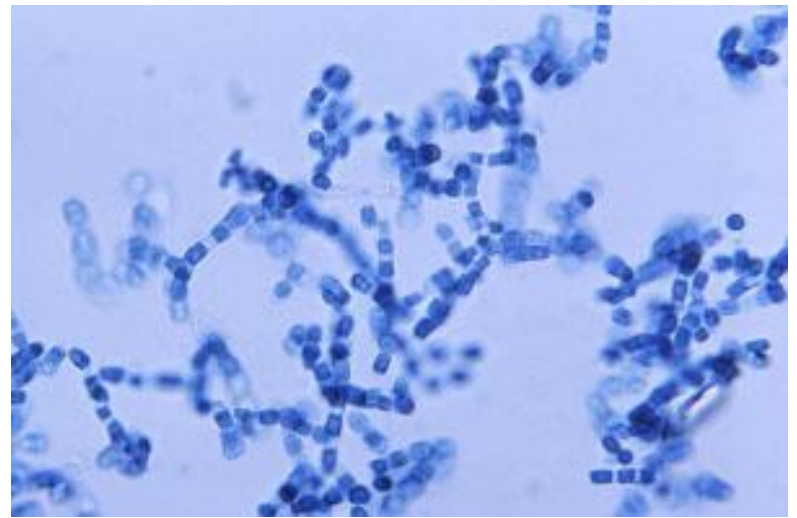


**OCCUPATIONAL
COCCIDIOIDOMYCOSIS
– TWO CASE STUDIES**

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VALLEY FEVER = COCCIDIOIDOMYCOSIS

- Infection in lungs from inhaled *Coccidioides immitis* fungus
 - Thrives in areas with hot summers, mild winters, desert climate
 - Sporadically distributed in top layers of soil – no feasible test
 - Infectious dose less than 10 spores
- Incubation period 1 to 3 weeks; Valley Fever is not spread person to person.



CLINICAL STATISTICS

- **Symptoms include fever, fatigue, chest pain, shortness of breath, headache, night sweats, skin rash, joint pain and weight loss.**
- **60% of those infected are asymptomatic.**
- **The disease has varying severity in those with symptoms – moderate severity (30%), pneumonia (10%), disseminated disease (1%).**

CLINICAL STATISTICS

- **Usually diagnosed based on serology (IgM and IgG antibodies), in vitro culture of the fungus from sputum, lung tissue histology, chest x-ray.**
- **Testing and diagnosis may be delayed because the symptoms present as flu or bacterial pneumonia.**
- **Moderate cases may or may not be treated with an anti-fungal agent (e.g., fluconazole). Pneumonia cases are typically treated. Treatment lasts months to years.**

CLINICAL STATISTICS

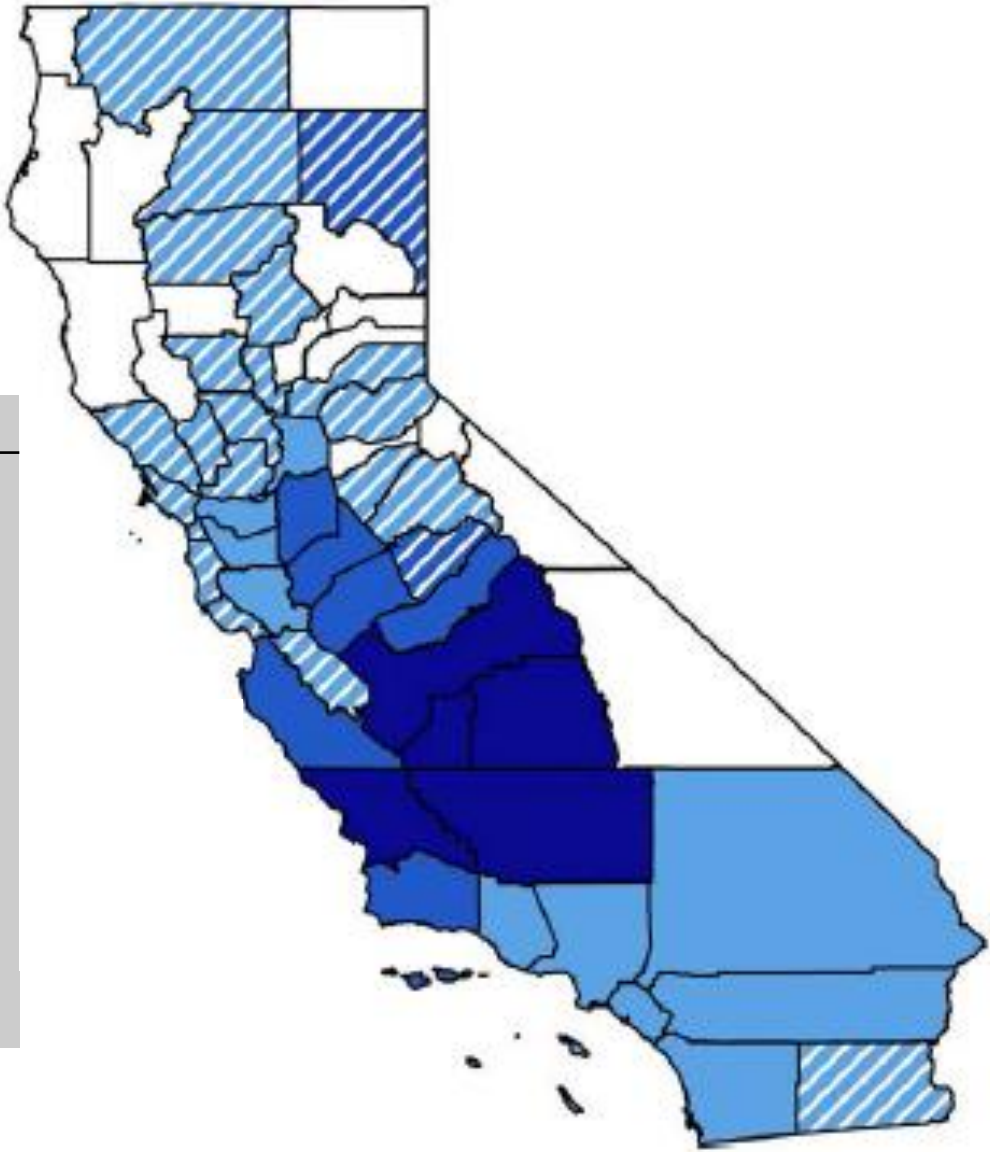
- **The infection can disseminate from the lungs to numerous tissues such as the bones, spine and brain. Disseminated infection is life-threatening.**
- **African Americans and Filipinos are at increased risk (about 10-fold) compared to Caucasians of disseminated infection.**

CLINICAL STATISTICS

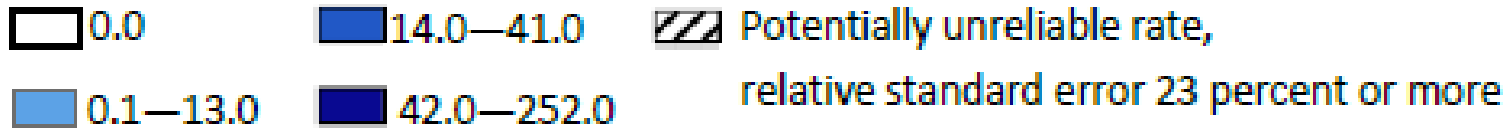
- **It is thought that resolved infection confers life-long immunity to re-infection, but re-activation of a prior severe infection sometimes occurs.**
- **A skin test is commercially available.**
- **There are no current skin testing data on the prevalence of past infection. It might be 10% to 30% overall in endemic areas. The percent would depend on the age group.**

Incidence by county, 2016

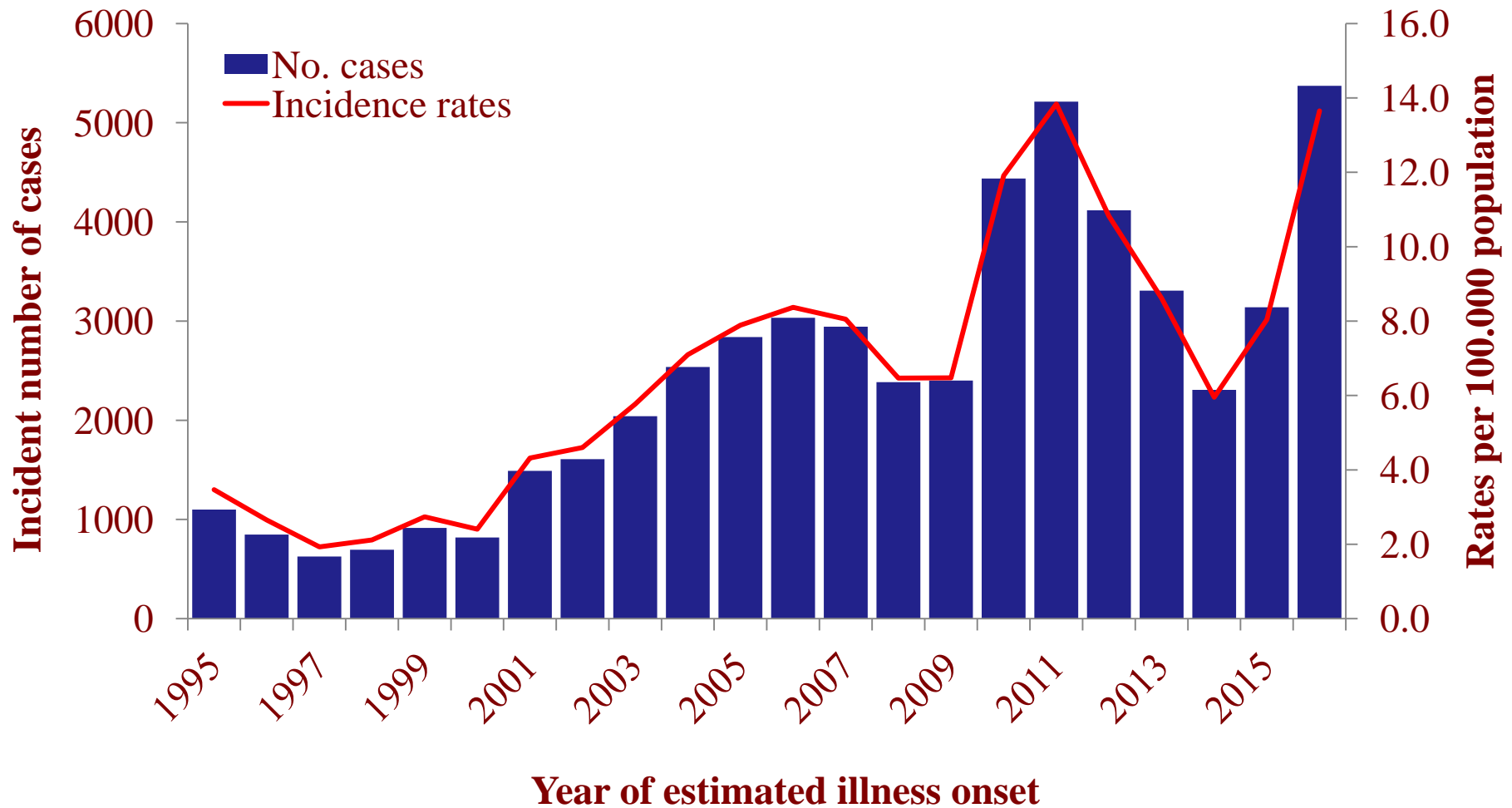
High rate counties*	Rate
Kern	251.7
Kings	157.3
San Luis Obispo	82.8
Fresno	60.8
Tulare	45.3
Madera	31.5
San Joaquin	25.3
*70% of CA cases	



Cases per 100,000 population



Valley fever cases and rates, CA, 1995–2016



Sondermeyer Cooksey et al (2017). Increase in coccidioidomycosis —California, 2016. *Morb Mortal Weekly Rep.* 66(31): 833–834

PHYSICAL FACTORS

- **The spores are barrel-shaped and 2 to 5 μm in length. A cited settling velocity corresponds to an aerodynamic diameter around 1 μm .**
- **There are no available data on the number of spores per mass/volume of infected soil, nor on the fraction of spores that can be aerosolized when that soil is disturbed.**
- **It is safe to say numerous spores can become airborne when soil is disturbed.**

PHYSICAL FACTORS

- **The fungus is not uniformly spread throughout the soil in an endemic region, but occurs in foci or hot spots considered “small” in size. The fungus is often found in rodent burrows.**
- **The fungus can be identified in soil via lab PCR methods, but at present there are no commercial labs that offer the analysis on soil samples.**
- **In an endemic region, absent soil testing, one should assume the fungus is present.**

OCCUPATIONAL EXPOSURE

- **Workers disturbing soil in endemic areas are at risk**
 - **Construction workers**
 - **Archeologists**
 - **Wildland firefighters**
 - **Military personnel**
 - **Mining, quarrying, oil & gas extraction jobs**
 - **Agricultural workers**
- **Exposure during wind, dust storms, travel**



EXPOSURE REDUCTION MEASURES

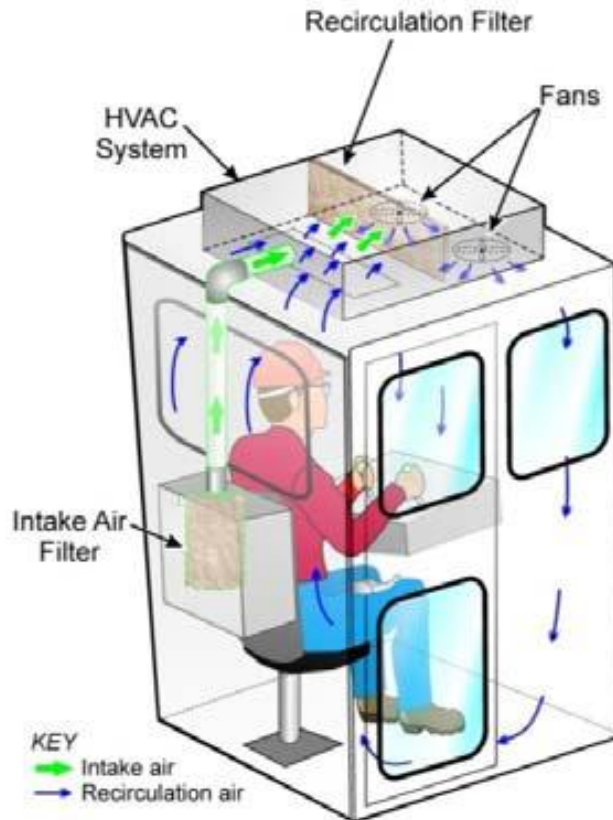
- **If soil is to be disturbed, keep the soil wet.**
- **However, wetting the soil may require adding chemicals to the water, and wetting the soil down to one or two inches below the surface will not prevent dust when excavating below that depth.**
- **The rate of water application (volume per time-surface area) for effective dust prevention is seldom, if ever, specified.**

EXPOSURE REDUCTION MEASURES

When disturbing soil with heavy equipment like an excavator or front-end loader, use a positive-pressure enclosed cab supplied with HEPA-filtered air.



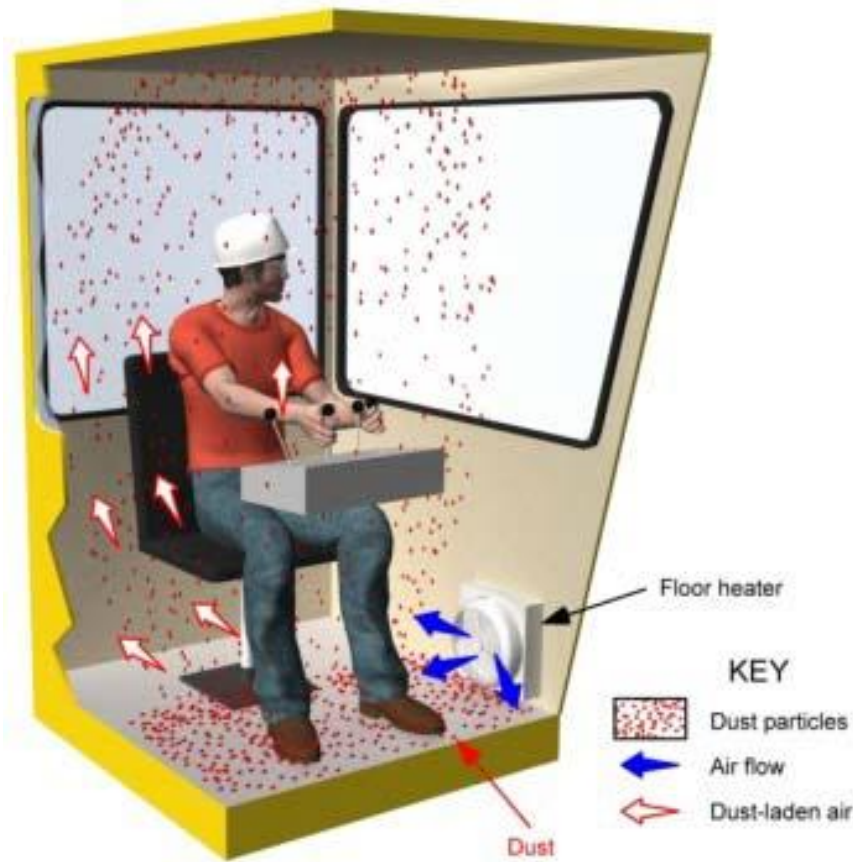
COMPONENTS OF EFFECTIVE CAB FILTRATION AND PRESSURIZATION



- **HEPA-filtered intake air**
- **Air heating and cooling capability**
- **Cab Positive Pressure (Reasonable Range): 0.08 to 0.25 inches water gauge**
- **Cab integrity (new door gaskets, seal cracks and holes)**

COMPONENTS OF EFFECTIVE CAB FILTRATION AND PRESSURIZATION

- **Keep windows closed!**
- **Remove in-cab dust sources (floor heater)**



EXPOSURE REDUCTION MEASURES

- **Stay upwind of the dust-generating work if feasible.**
- **If ambient conditions are too windy and dusty (based on pre-determined criteria), suspend work. Determining these criteria is not so easy.**
- **Wash off equipment and change clothes before leaving the work site.**

EXPOSURE REDUCTION MEASURES

- **Use respiratory protection when exposed to soil dust. At a minimum, wear a type N95 filtering facepiece respirator (FFR). A powered air purifying respirator (PAPR) with HEPA filter would be more protective.**
- **More on respirators at a later point.**
- **Respirator use requires a respirator program compliant with GISO 5144.**

THE CAUSATION QUESTION

In an endemic area, when a worker generates soil dust, or is a bystander to soil dust generated by others, and becomes infected, the usual question is:

**Was the infection due to the work or
or due to spores blown onto the site
from elsewhere?**

TWO SETTINGS

- 1. There are multiple cases among a group of individuals who did the same job or worked in the same area in the same time frame.**
- 2. There is an individual case with no coworkers or no information available about the health status of coworkers.**

MULTIPLE CASES

- **The standard approach for determining work-relatedness is to compare the group incidence rate to the population incidence rate in the general area.**
- **A related approach is considering the probability of observing the number of cases given the background risk.**

THE SINGLE CASE

- **Soil dust exposure measurements while performing job tasks may be available. Monitoring data for the ambient dust level (mostly soil) in the general region should be available.**
- **Soil dust exposure is treated as a surrogate for potential exposure to Cocci spores.**
- **One compares the cumulative soil dust exposure on the job versus off the job.**

MULTIPLE CASES – THE OILY WASH

- **In 2008 near the town of McKittrick in Kern County, CA, a highway overpass along State Route 33 was widened. Soil was excavated in the wash (called Oily Wash) below to create new footings.**
- **Water was not available for dust prevention for the first three days when most excavation took place.**
- **Respirators were not worn. The cab window of an excavator was kept open to aid in communication.**

MULTIPLE CASES – THE OILY WASH

- **Among 10 crew members who worked less than eight days in a two calendar week period, **7/10** developed severe Cocci pneumonia.**
- **The true number of cases was subsequently determined to be **9/10**.**

MULTIPLE CASES – THE OILY WASH

- **In 2008, the reported incidence rate in Kern County was 102 per 10^5 population, corresponding to a background risk of .00102.**
- **To be conservative, I assumed the background risk was 10-fold higher at .0102.**
- **The two-week risk was .000394, because:**

$$1 - (1 - .000394)^{26} = .0102$$

MULTIPLE CASES – THE OILY WASH

The binomial probability that among $n = 10$ persons, 7 or more are infected due to the background risk $p = .000394$ is less than one in a billion billion. There was no overt strong dust source nearby. It is safe to conclude the infections were due to airborne spores generated on the work site.

$$\Pr[k \geq 7 | n = 10] = \sum_{k=7}^{10} \binom{10}{k} (.000394)^k (0.999606)^{10-k} = 1.77 \times 10^{-22}$$

SOME INTERESTING FACTS

- **The workers were from non-endemic Northern California. The contracting agency knew about the Cocci risk, but did not inform the contractor.**
- **The contract specified using water for dust prevention. The contracting agency allowed the work to proceed without water use.**
- **The contracting agency refused the contractor's request to buy its water, available at a nearby pump station, due to a drought proclamation.**

SOME INTERESTING FACTS

- **The contracting agency contended the cases were not work-related. An independent medical legal examiner ruled the cases were work-related.**
- **The seven infected persons sued the contracting agency for damages and negligence. A jury ruled in their favor and awarded \$12 million. The verdict was upheld on appeal.**

ONE CASE – McKITTRICK OIL FIELD

- **In 2016, a male worker from outside California was hired on contract to operate heavy equipment and do laborer tasks on the McKittrick Oil Field in Kern County, CA.**
- **He arrived healthy on Day 1 and went home with severe Cocci pneumonia on Day 33.**
- **Information about the health status of coworkers was not available.**

ONE CASE – McKITTRICK OIL FIELD

- **On Day 11, the man went to an emergency room with initial symptoms. Up to midnight on Day 10, he had been in Kern County for 228 hours and on the oil field for 48 hours.**
- **The man described his tasks as very dusty. From Days 8 to 10, he pulverized dry soil with an open-cab skid steer. He said he was “engulfed” in a dust cloud.**
- **He was not provided a respirator. On Day 9, he found a dust mask in a tool shed and wore it thereafter. He was not fit tested. It is not known if the dust mask was NIOSH-approved.**

ONE CASE – McKITTRICK OIL FIELD

- **Summary respirable dust exposure data for construction jobs show an average of 1,480 $\mu\text{g}/\text{m}^3$ for heavy equipment operators and 4,760 $\mu\text{g}/\text{m}^3$ for laborers.**
- **I estimated that the man operated heavy equipment (e.g., the skid steer) 90% of the time and did laborer tasks (e.g., manual shoveling) 10% of the time.**
- **I estimated that his exposure level was reduced by 70% when he wore the dust mask.**

ONE CASE – McKITTRICK OIL FIELD

Accounting for (i) the hours spent as a heavy equipment operator and as a laborer, (ii) the average exposure intensity as a heavy equipment operator and as a laborer, and (iii) dust mask use for two days, I estimated the man's cumulative occupational respirable soil dust exposure to be:

66,500 $\mu\text{g-hr}/\text{m}^3$

ONE CASE – McKITTRICK OIL FIELD

- **The California Air Resources Board website indicates the average PM_{2.5} dust exposure level in Kern County in 2016 was 15.9 $\mu\text{g}/\text{m}^3$.**
- **I assumed this exposure level for the man while he was in his hotel room, where he spent most of his time.**
- **For 228 hours of ambient air exposure, the man's estimated cumulative ambient respirable soil dust exposure was:**

3,600 $\mu\text{g}\text{-hr}/\text{m}^3$

ONE CASE – MCKITTRICK OIL FIELD

- **I adjusted the work-related dust exposure value by subtracting off 48 hours of ambient exposure, and adjusted the ambient dust exposure value for 16 hours of respirator use.**
- **The final ratio of cumulative occupational soil dust exposure to cumulative ambient soil dust exposure was at least **19:1**.**
- **It is more likely than not his infection was due to airborne spores generated on the work site. An independent medical legal examiner agreed.**

SOME INTERESTING FACTS

- **The man went to an emergency room with some symptoms on Day 11. Tests for Cocci were not conducted until he returned to his home state several weeks later on Day 33.**
- **It seems that the ER physicians did not ask, or were not told, about the type of work he had been doing. This lack of information delayed the diagnosis and treatment, and likely resulted in a more severe infection.**

SOME INTERESTING FACTS

- **A training video downplayed the infection risk by stating a person could be “infected anywhere in California due to spores carried by winds.”**
- **The statement is true in theory, as shown by the “Tempest from Tehachapi,” but false in reality.**
- **In 2016, there were no reported cases in 15/58 California Counties, whereas there were 2,238 reported cases in Kern County.**

SOIL DUST AS A SURROGATE

- **Other than in a laboratory environment, Cocci spore exposure will be accompanied by soil dust exposure.**
- **The idea that everyone in an endemic region is subject to a relatively low background infection risk is consistent with ongoing exposure to a relatively low spore concentration and to a relatively low soil dust concentration in ambient air.**

SOIL DUST AS A SURROGATE

There is no reason that the spore count concentration (# per m³) must always be in proportion to the soil dust mass concentration (mg per m³), but it is a conservative assumption in favor of non-occupational exposure.

WHY IS IT CONSERVATIVE?

- **Because if spores are emitted into air on a work site, the spore concentration per mg/m³ of soil dust will be greatest on the site and decrease with distance away from the work site.**
- **As the spores and soil particles disperse away from the emission point, the soil dust concentration falls off less rapidly than the spore concentration, because the soil cover is always emitting more soil particles into the air.**

RESPIRATORY PROTECTION

It is thought it takes just one Cocci spore to infect a person. If that is true, infection risk adheres to a one-hit model:

$$**R = 1 - \exp(-D)**$$

where D = the expected # spores received

RESPIRATORY PROTECTION

- **If a respirator allows fractional penetration P , it reduces the expected dose received to $P \times D$, and reduces infection risk according to:**

$$R = 1 - \exp(-P \times D)$$

- **For a type N95 FFR, the assumed $P = 0.1$**
- **For a high quality PAPR, the assumed $P = .001$.**

AN EXAMPLE

- For $R = 0.7$ with no respirator use (per the Oily Wash project), the expected dose $D = 1.2$.
- For a N95 FFR with $P = 0.1$, the infection risk $R = 0.11$ (or **11%**).
- For a PAPR with $P = .001$, the infection risk $R = .0012$ (or **0.12%**).

RESPIRATORY PROTECTION

- **If the infectious dose is greater than one spore, the one-hit model equation does not apply.**
- **However, one result is that for a given expected dose value, respirator use is more effective at preventing infection than described by the one-hit model.**

RESPIRATORY PROTECTION

- **The one-hit model does not consider the value of the dose beyond zero versus one or more spores.**
- **But the dose likely determines the severity of the infection. Limited primate test data from 1962 showed that 50 spores caused little destruction of lung tissue and no deaths, but 300 spores caused extensive lung damage and 60% mortality.**
- **If respirator use did not prevent an infection, it could still reduce the severity of the infection.**

SOME QUESTIONS

- **Are work-related Cocci pneumonias more severe because the dose of spores received is higher?**
- **Is it feasible to use water spray to knock down airborne respirable particles on construction sites?**
- **Is it feasible to promote preventive measures via requirements attached to public agency permits?**

SOME REFERENCES

Nicas M (2018): A point-source outbreak of Coccidioidomycosis among a highway construction crew, *J. Occup. Environ. Hyg.* 15:57-62

Nicas M (2018): Occupational Coccidioidomycosis in a Heavy Equipment Operator, to appear in the December issue of *J. Occup. Environ. Hyg.*

Pappagianis D and H Einstein (1978): Tempest from Tehachapi takes toll or Coccidioides conveyed aloft and afar, *West. J. Med.* 129:527-530