Strategies to Curtail Dust-caused Illness in Arizona: A Policy Memorandum to the Arizona Congressional Delegation

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Abstract: This policy memo discusses the growing concerns of dust storms within US southwestern deserts and, in particular, Arizona. Since the 1990s, the frequency of southwestern desert dust storms has dramatically increased. This increase has partially fueled a rise in respiratory health diseases, such as valley fever and severe lung tissue damage from dust particles. We propose two complementary policy solutions for near- and long-term benefit: (1) an assessment of potential vaccine pathways and appropriate federal research and development support and (2) an improved early warning system to alert residents to the health impacts of dust storms.

I. Introduction

Since the 1990s, dust storms in the desert southwest have increased in frequency by 240% (Tong et al. 2017), exacerbated by drought, climate change, and soil disturbance. Dust storms can lead to numerous adverse health effects. They carry toxic metals, like arsenic and mercury, and particles that penetrate lung tissue and cause severe respiratory problems (Griffin 2007). The increased frequency of southwestern desert dust storms has been positively correlated with increased incidence of valley fever (Tong et al. 2017). Valley fever stems from *Coccidioidomycosis* infections, a fungus that is located within the top 2-8 inches of dry soil in the southwestern U.S, especially in California and Arizona (Fisher et al. 2007). Adverse health effects include fever, shortness of breath, severe cough, pneumonia, and, in extreme cases, death. Patients with compromised immune symptoms are particularly at risk. In 2017, there were 6,885 reported cases of valley fever in Arizona—a 98% increase from 1990 (Arizona Department of Health Services). Action is critical for Arizona residents. We propose a suite of responses to curtail the prevalence of respiratory diseases caused by dust storms through increased research funds for vaccine discovery and robust early warning systems.

II. Current healthcare impacts

Dust storms can cause and aggravate a variety of cardiovascular and respiratory illnesses—from bacterial infections to asthma to stroke—by transporting particulate matter into the lungs where it can trigger biological responses like inflammation and cardiac or nervous system dysfunction (Goudie 2014). Crooks et al. (2016) reported a 7% increase in non-accidental mortality in the days following dust storms in California and Arizona. Dust storms in the American southwest spread fungal spores from *Coccidioides immitis* and *Coccidioides posadasii,* which are responsible for valley fever. While the overall relationship between valley fever infection rates and weather varies by location, Centers for Disease Control and Prevention studies reported strong predictive associations in Maricopa County, AZ between valley fever incidence and dust storm conditions including drought indices, wind, and particulate matter below 10 microns (Roach et al. 2017). Particulates of this size can be inhaled into the lungs, potentially carrying fungal spores or other irritants (Lader et al. 2016).

Hospitalizations and treatment of valley fever comes at a substantial cost to affected communities, with all costs below listed below in 2020 dollars based on the US Department of Labor Consumer Price Index (US Bureau of Labor Statistics, n.d.). Sondermeyer et al. (2013) found that hospital charges related to valley fever reached $217 million annually in California from 2000-2011. Costs rose to about $455 million in 2017 and analysis of indirect costs showed a total of $287 million of lost revenue and labor (Wilson et al. 2019). Tsang et al. (2010) found that valley fever hospital charges reached approximately $109 million in Arizona for 2007. Of the individuals affected, 74% of patients were employed. These patients missed a median of fourteen days of work to recover, seven of which were spent at the hospital. They accrued a median of $62,450 in direct charges per person (Tsang et al. 2010). As this study only included lab-confirmed diagnoses, the reported 1,093 primary diagnosis of valley fever likely underestimated the number of incidences and associated costs in 2007. While limited in temporal and spatial coverage, these studies underscore the intense personal costs of valley fever. Increasing dust storm severity and frequency are likely to increase the rate of valley fever infection and the associated burdens on patients and the healthcare system.

III. Current policies and efforts to curtail the impact of dust storms in Arizona

As of October 2019, seven of fifteen Arizona counties did not meet US Environmental Protection Agency (EPA) air quality standards, in part due to dust (ADEQ 2019). The counties of Maricopa, Pinal, Pima, and Yuma do not meet air quality standards yet contain almost 85% of Arizona's population (Arizona Office of Economic Opportunity 2019). In response, the Arizona Department of Environmental Quality (ADEQ) submitted a Standard Implementation Plan (SIP) in 2012 to reduce natural and anthropogenic dust sources and improve air quality (ADEQ, n.d.). The SIP aims to reduce non-natural dust sources and other larger particles (PM_{10} or particulate matter under 10 microns) by 5% every year in Pinal and Maricopa Counties until attainment is reached (National Archives and Records Administration 2014).

While many dust storms occur naturally, construction, business, and agriculture contribute to Arizona's failure to meet EPA air quality standards by generating dust from their activities. The Maricopa County Air Quality Division (MCAQD) details the dust control process and program, which includes a dust control permit, dust abatement handbook, dust reduction incentives, and other resources (Maricopa County Air Quality Division 2008). Identified non-natural dust source sites, such as construction sites, are required to have a dust control plan. The dust abatement handbook includes suggestions for dust control, such as spraying water during earthwork or applying a chemical treatment to an area to prevent erosion of the soil surface. Since every site is unique, dust can be mitigated in different ways. MCAQD uses opacity, or how much light is transmitted through air particulates, as its air quality metric. Opacity is established by qualitative on-site observations following a 6-step protocol. However, all sites have a hardline regulatory limit of 20% opacity during earthwork activities (Maricopa County Air Quality Division 2008). Violations can be reported by public complaints or annually by MCAQD inspectors, which leads to review by the Air Pollution Hearing Board. MCAQD has the authority to penalize those in non-compliance up to $10,000 per violation, per day. This has driven site owners to incorporate dust abatement practices to prevent cost from penalties. State agencies such as the Arizona Department of Transportation (ADOT) are also held to these regulations.

Unfortunately, there is not yet a viable solution to reducing natural dust pollution because of the vast amounts of dust-producing land across the desert southwest. Arizona has deployed air quality information and weather report alerts, cellular notifications of dust storms, and highway warning signs while continuing to search for economical methods for reducing natural dust events (Totiyapungprasert and Nicla 2019).

IV. Policy proposals

i. Proposal 1: vaccine development

Robust dust control and public communication efforts will still leave some residents vulnerable to valley fever. Development of valley fever vaccines could curtail the disease across the southwestern US Given the increasing prevalence of valley fever, an effective and affordable vaccine could substantially reduce costs and suffering. Barnato et al. (2001) estimated that a valley fever vaccine could substantially lower mortality and disability rates resulting from valley fever infections. Researchers have investigated various pathways for a valley fever vaccine, including one reported in 1993 that advanced to trials in humans but that failed to produce statistically significant reductions in the incidence of valley fever (Pappagianis and Valley Fever Vaccine Study Group 1993). More recently, Van Dyke et al. noted several promising lines of development, but none advanced to human trials (2019). The National Institutes of Health (NIH) has invested an estimated $42 million in research related to valley fever from 2014-2020.[1] A portion of this funded research was devoted to vaccine development,[2] including funding to test a vaccine for dogs[3] and a clinical trial in humans that was terminated due to low enrollment rates.[4]

The development of vaccines for fungal infections, such as valley fever, faces scientific challenges due to the unique characteristics of fungal infections. Many patients who could most benefit from vaccines, for example, are immunocompromised. Systemic characteristics of the research and development ecosystem, however, play an important role in limiting progress on valley fever vaccines. Van Dyke et al. noted the relatively small potential private market for a valley fever vaccine as a potential inhibitor of further development (2019). Further, Spellberg noted that understanding of fungal diseases has increased in recent decades, but "the biggest barrier to development of fungal vaccines is the lack of available capital to translate discoveries made at the bench into biological agents used at the bedside" (2011). The health and economic impacts of valley fever demand the consideration of public investment in the development of valley fever vaccines. Further, public investment in vaccine research around valley fever could spur new avenues for addressing other fungal diseases afflicting millions worldwide (Brown et al. 2012). Building on existing vaccine research, we propose a dual approach to furthering federal support of research and development (R&D) in pursuit of better health outcomes for residents of the southwest.

Step 1: Assessment for valley fever vaccine pathways

An assessment of potential valley fever vaccine development pathways should be conducted to reevaluate the potential impact of a valley fever vaccine and identify promising lines of research and development. Such an assessment should involve patient advocates, researchers, pharmaceutical companies, health practitioners, policy makers, and clinicians (Nelson et al. 2011). The involvement of these stakeholders better accounts for value differences in assessing costs and benefits and uncertainties in potential pathways for R&D. Assessment should be steered towards identifying potential valley fever vaccine development pathways and moving beyond current systemic limitations on R&D. This assessment should guide decisions about future research and federal investment allocated to a specific federal agency.

Step 2: Federal investment for valley fever vaccine development

The National Institute of Allergy and Infectious Diseases (NIAID) has invested in valley fever research since at least 2014 (NIAID 2018). However, NIAID, and more broadly NIH, seeks to promote fundamental knowledge through broad funding programs and investigator-driven proposals evaluated mostly on scientific merit (NIH 2015) merit. Another research program that would complement research conducted by the NIAID is the more mission-driven Congressionally Directed Medical Research Programs (CDMRP), which is administered by the Department of Defense. The CDMRP focuses on clinical and application-based research (CDMRP 2020). CDMRP has funded high

[1] Budget estimate based on data from NIH available at https://report.nih.gov/categorical_spending.aspx.
[2] Details of individual funded projects categorized by NIH as valley fever are available at https://report.nih.gov
[3] See a 2017 press release from the University of Arizona's Valley Fever Center of Excellence: https://uanews.arizona.edu/story/nih-awards-48m-valley-fever-center-work-dog-vaccine.
[4] Details of this clinical trial are available at https://clinicaltrials.gov/ct2/show/study/NCT02663674

risk, high reward research on a variety of diseases since its inception in 1992.

Past cost estimates for the development of a valley fever vaccine have varied. A National Academies of Science assessment conducted in 2000 estimated that a valley fever vaccine might cost $360 million, or $530 million today when adjusted for inflation.[5] Rappuoli et al. (2019) estimated that developing a vaccine costs upward of $1 billion and occurs in the following three stages: discovery, early development, and late development. The discovery stage's primary goal is to determine a formulation that combats the target disease, which is estimated to cost approximately 10% (or $100 million) of the commercialization budget. Using the budget from Rappuoli et al. (2019) as a starting estimate, a $100 million investment over five years to NIAID and CDMRP could catalyze progress towards a vaccine. As a comparison, the NIH spent approximately $42 million towards valley fever research from fiscal years 2015-2020. The proposed $100 million would more than double the allocated funds for valley federal research. Furthermore, allocating $100 million towards valley fever vaccine development is a fourth of the cost currently spent on valley fever illness (Wilson et al. 2019). Yet, developing a valley fever vaccine could significantly curtail future costs of treatment.

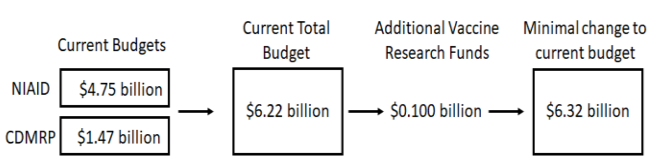

Figure 1: Additional research funds included within the NIAID and CDMRP spending budgets for valley fever vaccine development have a minimal impact on the organization's total budget.

The NIAID's requested budget for fiscal year 2020 was $4.75 billion, and the CDMRP received $1.47 billion for fiscal year 2019. The budget suggested for valley fever vaccine development, assuming that $100 million was distributed over one fiscal year, is 1.6% of the *annual* budget for these programs combined. The impacts on department budgets are shown in Figure 1. The specific amount of federal funds allocated to each agency should be determined during the assessment step (refer to *Step 1*).

ii. Proposal 2: expanded digital advisory and warning alert messaging

Mobile phone warning alerts could help people avoid exposure to dust during dust storms or other periods of high risk. Currently, EPA provides the AirNow mobile application and EnviroFlash emails to show the air quality index at the location of the subscriber (US EPA, n.d.; "Enviroflash-Home" n.d. "AQI Calculator, n.d.; "Air Quality Index (AQI) Basics", n.d.). However, these voluntary programs have limited user bases and limited functionality. For example, EnviroFlash will only alert a user to poor air quality in the location that the user originally declared as their location, determined by the user's registered zip code rather than real-time air quality information based on the user's current location. Many smartphone users use pre-installed or third party weather applications that could enable broader reach for dust-related alerts. Desert residents also receive mobile push notifications related to dust storms based on a user's specific geographic location from the National Weather Service's (NWS) emergency alert system. In Phoenix, AZ, NWS is responsible for creating mobile alerts to warn residents in the Phoenix area of incoming dust storms, when dust storms are potentially dangerous (Waters 2019).These alerts are also shown in transit signage throughout Maricopa County for those without mobile devices. However, the alerts (Table 1) focus on road visibility rather than communicating potential health impacts of the storm. We propose a more robust public education and messaging system with information and a system infrastructure that is already available.

Emergency alert messaging should incorporate EPA's air quality index (AQI) and health information, specifically for particle pollution (US EPA, n.d.). The corresponding AQI and health warnings are shown in Table 2. For example, automatic push notifications sent when air quality is "Unhealthy (Level 4)", "Very Unhealthy (Level 5)", or "Hazardous (Level 6)". Notifications would include the current air quality index and associated health risks to empower residents with information that can help them stay

[5] We calculated inflation using the US Bureau of Labor Statistics Consumer Price Index calculator available here: https://data.bls.gov/cgi-bin/cpicalc.pl.

Alert	**Description**
Dust advisory	Localized blowing dust reducing visibilities to 1 mile or less, but greater than ¼ mile, is occurring or imminent. *Note: These advisories are for localized, short-duration events typically lasting for 90 minutes or less.*
Dust storm warning	Localized blowing dust reducing visibilities to ¼ mile or less is occurring or imminent. *Note: These warnings are for localized, short-duration events typically lasting for 90 minutes or less.*
Blowing dust advisory	Widespread blowing dust reducing visibilities to 1 mile, but greater than ¼ mile, is occurring or imminent. *Note: These advisories are for widespread, long-duration events typically lasting for 90 minutes or more.*
Blowing dust warning	Widespread blowing dust reducing visibilities to ¼ mile or less is occurring or imminent. *Note: These warnings are for widespread, long-duration events typically lasting for 90 minutes or more.*

Table 1: NWS Phoenix watch, warning, and advisory criteria for dust (from least to most severe)

Level	**Air quality index**	**Health advisory**
1	Good	None
2	Moderate	Unusually sensitive people should consider reducing prolonged or heavy exertion.
3	Unhealthy for Sensitive Groups	People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.
4	Unhealthy	People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion.
5	Very Unhealthy	People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.
6	Hazardous	Health warnings of emergency conditions. The entire population is more likely to be affected.

Table 2: Air quality index for particle pollution

safe. Below is an example alert system that incorporates health risks associated with dust:

Dust storm warning in this area—localized blowing dust reducing visibility to ¼ mile. Very unhealthy air quality that could lead to an increase of respiratory disease and valley fever. To reduce your risk: sensitive groups avoid all physical activity outdoors; everyone else should avoid prolonged or heavy exertion outdoors. Warning in effect until [Month, Day, Year] or until an all clear is released.

This notification would also include the date when the warning is no longer expected to be in effect or when the air quality index reaches "Moderate (Level 2)" levels. The EPA has determined that a 35.4 micrograms/m^3 or less concentration of particulate matter that is less than 2.5 microns in size is safe for the public. For particulate matter that is 2.5-10 microns in size, a concentration of 154 micrograms/m^3 or less is safe for the public (US EPA 2019). These concentrations are equal to a "moderate" air quality index (level 2). Anything above "moderate" has been determined unhealthy by the EPA (US EPA 2019).

Monthly reminders will be issued until the warning is no longer in effect, or bi-weekly if people opt-in for more frequent updates. If the air quality has not reached an acceptable level at the expected warning end date, another warning will be issued following the same format. Below "Very Unhealthy" and "Hazardous" air quality levels, users would have to opt-in for alerts.

Anyone with a mobile phone in the area of an incoming dust storm would be alerted of the correct precautions to take for their health and safety. The National Oceanic Atmospheric Administration, which houses the NWS, partners with EPA to provide daily air quality forecasts, suggesting an existing organizational pathway for testing and updating messaging.

V. Conclusion

Dust storm frequency in Arizona and the southwestern US is increasing with associated significant health risks, such as valley fever and lung tissue damage caused by dust particles. This memorandum recommends the following policy proposals: (1) Evaluating potential pathways for vaccine development and appropriate financial support for R&D through the NIH and CDMRP in the DOD, and (2) Expanding low-cost early warning indicators that forewarn residents of poor air quality and health hazards associated with dust storms.

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