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U.S. AFFILIATE OF INTERNATIONAL PHYSICIANS FOR THE PREVENTION OF NUCLEAR WAR

AIR POLLUTION AND COVID-19:

A DANGEROUS COMBINATION

A Report from Physicians for Social Responsibility

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Photos (pp. 3, 4, 8, 13) Courtesy of WildEarth Guardians



Counties – counties that experienced high levels of oil and gas development in 2020.

- Oil and gas production sites are a major contributor to air pollution.
- Chronic exposure to air pollution worsens serious health conditions, including asthma, COPD, and lung cancer; premature birth, birth defects, and developmental delays; heart disease, obesity, kidney disease, liver dysfunction, and type 2 diabetes.
- Pre-existing diseases or medical conditions increase the risk of hospitalization or death in patients diagnosed with COVID-19.

Given these facts, this report asks an important question:

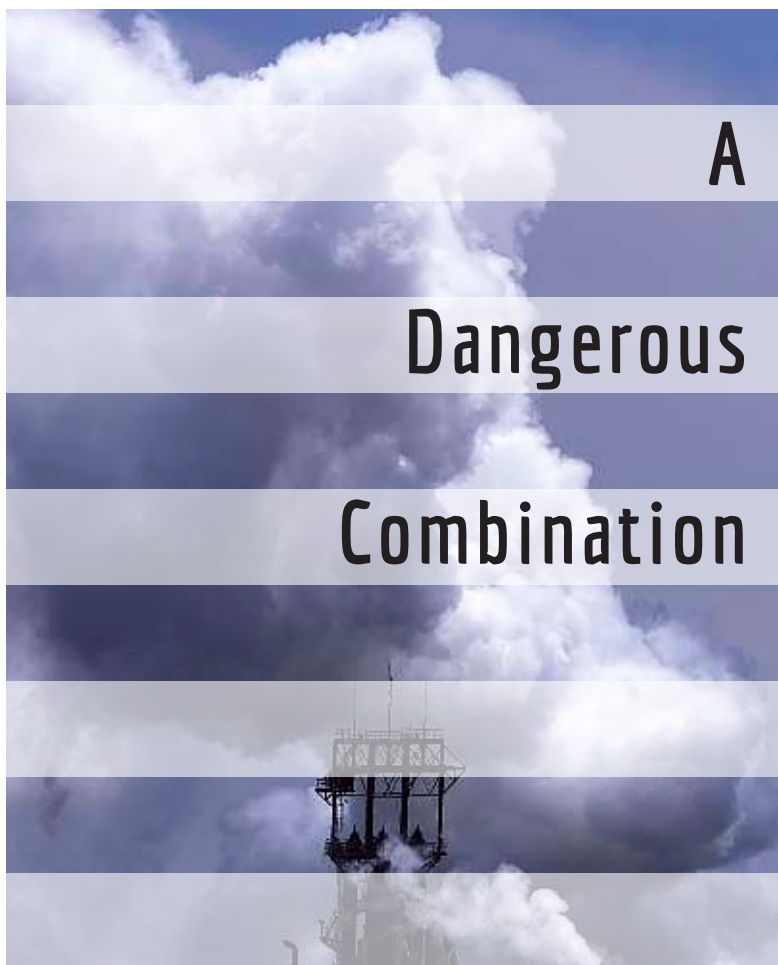
Does exposure to air pollution from oil and gas extraction and processing increase rates of infection and death from COVID-19?

We examined five counties in Colorado and five in New Mexico, each with significant oil and gas operations, and made the following initial observations.

The number of COVID-19 cases was higher than expected in three counties and lower than expected in two. The number of cases was disproportionately high among people aged 20-29 years and Hispanics. More COVID-19 deaths were observed than expected in Adams, Broomfield, and Weld

The number of COVID-19 cases was higher than expected in three counties and lower than expected in two. Disproportionately high levels of cases were observed among people aged 20-49 years and Native Americans. Higher numbers of deaths from COVID-19 than expected were found in one county and lower than expected in four. Adjustment for age and/or race would likely modify these results, but age and race distributions for COVID-19 deaths are not publicly available in New Mexico.

- As oil and gas operations add to the cumulative air pollution burden, **take all available steps to reduce pollution from these sources.**
- **Because oil and gas pollutant emissions can be controlled, focus efforts on reducing those emissions**, whether from leaks, flaring, blowdowns and other deliberate releases, or other causes.
- Our study was an initial inquiry into impacts of oil and gas pollution on COVID-19 and did not generate definitive answers. Rather, this report constitutes only a first step in that inquiry. **Further research is needed.**



On March 11, 2020, the World Health Organization declared COVID-19 a global pandemic. Two days later, the President of the United States issued a national state of emergency declaration. Since then, the novel coronavirus has infected millions around the world and killed more than 400,000 Americans.¹

This report explores the potential for exposure to air pollution from oil and gas operations in two Mountain West states to exacerbate infections and deaths due to COVID-19.

Air Pollution Harms Health

Chronic (continued or repeated) exposure to air pollution worsens many serious health conditions and in fact causes some. Decades of research link air pollution with a multitude of cradle-to-grave adverse health impacts including complications of pregnancy and poor birth outcomes, birth defects and childhood developmental delays.² Breathing polluted air is an important cause of chronic obstructive pulmonary disease (COPD) in adults and of asthma in both children and adults. It is associated with the exacerbation of asthma and COPD and heart disease, and fine particulate matter can cause lung cancer.³ People suffering from mental health conditions are adversely impacted in communities degraded by air pollution.⁴ In all, according to estimates from the World Health Organization, more than four million

people worldwide die prematurely as a result of exposure to ambient (outdoor) air pollution.⁵

Air pollutants harm the body via several mechanisms. Fine particulate matter and other air toxics are known to injure the hair-like cilia that line the respiratory tract and act as first-line defenders to remove harmful microorganisms. Inflammation and cellular damage from pollution hamper the immune system charged with protecting the body from invading organisms like coronavirus. When these natural defenses are impaired, infections from respiratory viruses like coronavirus are more likely to occur. Likewise, severe complications and higher death rates from respiratory infections are expected.⁶

Long-term exposure to air pollution is also associated with the development of obesity and its related health complications of hypertension, kidney disease, liver dysfunction, and type 2 diabetes. These so-called “comorbidities,” or simultaneously existing diseases or medical conditions, are known to increase the risk of poor outcomes in patients diagnosed with COVID-19.⁷

Air Pollution Exacerbates COVID-19

Coronavirus is a respiratory virus that initially gains access into cells lining the airway. The virus replicates inside the cell before injuring or killing it, and then moves on to other cells, causing more damage. Symptomatic individuals with COVID-19 typically complain of respiratory symptoms: nasal congestion, cough, and shortness of breath. In addition, fever or chills, headache, fatigue and muscle aches are commonly reported.⁸ Neurological symptoms, including loss of smell and taste, and problems with cognition (“COVID-19 Fog”), are not unusual.⁹

Severe damage to the respiratory tract in patients with COVID-19, in combination with lungs already damaged from

breathing polluted air, creates an increased risk factor for poor health outcomes. Early in the pandemic, researchers studying the regional impact of COVID-19 in Northern Italy’s Po Valley noted that “the highest number of COVID-19 cases were recorded in the most polluted regions with patients presenting with more severe forms of the disease requiring ICU admission.” Mortality was two times higher compared to other regions in Italy.¹⁰ In China, a study examined short-term exposure to air pollution and found “a significant relationship between air pollution and COVID-19 infection,” with positive associations seen with large and small particle pollution (PM10 and PM2.5), nitrogen dioxide, and ground-level ozone.¹¹

In the United States, new research from the Harvard T.H. Chan School of Public Health indicates that exposure to even small increases in long-term fine particle pollution (PM 2.5) is associated with an increase in the death rate from COVID-19.

In the United States, recent research from the Harvard T.H. Chan School of Public Health indicates that exposure to even small increases in long-term fine particle pollution (PM 2.5) is associated with an increase in the death rate from COVID-19. The researchers underscored the importance of enforcing existing regulations that limit air pollution in order to protect public health during (and after) the pandemic.¹² Another study from the Georgia State University Andrew Young School of Policy Studies also found a relationship between PM 2.5 exposure and disease and death from COVID-19.¹³

Chronic exposure to air pollution and high rates of COVID-19 disproportionately affect Black people, Native Americans, and Latinx people.¹⁴ In large measure this reflects discriminatory housing patterns: Poor people and minorities are more likely to live in heavily polluted communities. People living near fixed sources of air pollution (factories and power plants) and mobile sources (highways, shipping lanes, airports) experience greater health impacts from pollution. We now know that this same population is experiencing higher numbers of COVID-19 infections, clinical complications, and deaths.¹⁵ These

facts should concern all Americans, not just those living in environmental justice communities bearing the burden of industrial and fossil fuel pollution in their neighborhoods.

These preliminary findings shouldn't be surprising. As the COVID-19 public health crisis continues to unfold across the United States and around the world, the association of air pollution and poor clinical outcomes from novel coronavirus infections is becoming increasingly apparent.

Gas and Oil Operations Are a Major Source of Air Pollution

Communities in proximity to oil and gas operations — extractive processes with significant downstream impacts — may also be at increased risk for health impacts from air pollution and COVID-19.

The boom in oil and gas extraction resulting from innovations in hydraulic fracturing and horizontal drilling technologies has brought the industrial activities associated with this extraction closer to more people than ever before.¹⁶ Nationwide, more than 17 million people live within one mile of at least one oil or gas well.¹⁷ Encroachment of oil and gas extraction sites into residential communities leaves a large and lasting source of air pollution.

Every stage of oil and gas extraction activities has been associated with the emission of air pollutants. Air pollutants are emitted from extracted oil and gas, produced water, drill cuttings, drilling muds, hydraulic fracturing fluids, and flares, as well as from the diesel engines used to power trucks, drill rigs, and hydraulic fracturing equipment. These air pollutants include fine particulate matter and hazardous air pollutants, as well as nitrogen oxide and volatile organic compounds.^{18,19}

Nitrogen oxides combine with volatile organic compounds in the presence of sunlight and heat to form ground-level ozone, a potent air pollutant that stunts the growth of children's lungs, damages lung tissue, and reduces every person's lung function, making it harder for adults with COPD and children with asthma to breathe.²⁰

Oil and gas operations are a major contributor to regional ozone pollution in Colorado.²¹ Human health risk assessments in Colorado indicate increased risks of respiratory effects for people living nearest to oil and gas extraction sites.^{22, 23, 24} EPA scientists estimate that fine particulate matter and ozone-related premature deaths

attributable to oil and gas extraction activities will reach 1,970 per year in the United States, with the population in Colorado's Denver Julesburg Basin and New Mexico's Permian Basin experiencing some of the highest rates. Additionally, nitrogen oxide, volatile organic compounds, fine particulate matter, and hazardous air pollutants emissions are especially abundant at compressor stations, which keep oil and gas flowing through long-distance pipelines.²⁶

We now know that oil and gas extraction activities (fracking) contaminate the air we all depend on and may make people sick. The

impacts of fracking on human health are well-documented in the "Compendium of Scientific, Medical, and Media Findings Demonstrating the Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)," published in 2019 by Physicians for Social Responsibility and Concerned Health Professionals of New York. (New York State has successfully banned fracking.) That report, which summarizes more than 1,700 peer-reviewed studies and investigative reports, found "no evidence that fracking can operate without threatening public health."²⁷

As the COVID-19 public health crisis continues to unfold across the United States and around the world, the association of air pollution and poor clinical outcomes from novel coronavirus infections is becoming increasingly apparent.

Air Pollution and Coronavirus: A Dangerous Combination

It is clear that all around the United States, Americans suffer chronic disease and early death from breathing air pollution. Equally clear is that those living in proximity and inhaling the chemical pollution produced at every point of oil and gas operations are also at higher risk of experiencing adverse health impacts. The impairment of respiratory tract defenses and reduced lung function arising from long-term exposure to air pollution increase the risk of contracting coronavirus and developing complications from it, especially in people suffering from chronic medical conditions.

This report examines the possibility that the invisible particles and vapors coming from oil and gas production sites, by increasing the pollution burden on the respiratory system of local residents, increases their vulnerability to the novel coronavirus. If this is the case, they are a dangerous and deadly combination.

Methodology

Our goal in reviewing the currently available evidence on COVID-19 is to determine if Colorado and New Mexico populations living in areas with active oil and gas production sites may be at a higher risk for COVID-19 transmission, morbidity (disease) and mortality (death). One element of our review was to determine if Colorado and New Mexico counties with active oil and gas production sites were experiencing more COVID-19 cases and deaths than would be expected, based on state-level rates. The results of this initial ecological analysis could then generate hypotheses for future studies.

We selected five counties in Colorado and five in New Mexico to study ; they include the top three oil- and gas-producing counties in each state and counties in the major oil- and gas-producing basins in each state. For each county, we used a standardized ratio method to compare the cumulative number of COVID-19 cases and deaths observed to the cumulative number of COVID cases and deaths that would be expected if state-wide rates prevailed. These are

known as the standardized incidence ratio (or SIR) and the standardized mortality ratio (or SMR), respectively. The methods we used are detailed on the next page. Because COVID-19 incidence and mortality vary by age and race/ethnicity as an indicator of vulnerability to COVID-19 exposure [see Figures, pages 9-12](#) , we adjusted the SIRs and SMRs for age and race. The data sources we used were publicly available for county-level and state-level data on population, demography, and COVID-19 rates.

Table 1: Population Counts and 2020 Oil and Natural Gas Produced in Colorado and New Mexico Counties

County	Population Count	Oil Produced as of August 2020 (Barrels)	Natural Gas Produced as from Jan through August 2020 (million cubic feet)	Basin
Colorado (total population = 5,761,907)				
Adams County	517,440	2,094,665	18,079,608	Denver Julesburg
Broomfield County and City	70,799	557,218	5,540,822	Denver Julesburg
Garfield County	60,103	25,473,457	262,245,138	Piceance
La Plata County	56,353	19,983,872	146,431,864	San Juan
Weld County	323,252	99,304,230	627,958,864	Denver Julesburg
New Mexico (total population = 2,101,730)				
Eddy County	58,162	82,786,314	426,887,164	Permian
Lea County	70,832	101,837,823	334,538,149	Permian
Rio Arriba County	39,118	619,071	152,208,968	San Juan
Sandoval County	145,153	1,443,077	6,537,294	San Juan
San Juan County	128,046	2,568,798	220,047,734	San Juan

Description of Methodology

We obtained data on observed cumulative COVID-19 cases and deaths in the selected counties, as well as in Colorado and New Mexico statewide, as of October 12, 2020 from USAFacts (<https://usafacts.org/visualizations/coronavirus-covid-19-spread-map/>). Using 2019 Colorado state and county population estimates from the Colorado Health Information Dataset (https://cohealthviz.dphe.state.co.us/t/HealthInformaticsPublic/views/CoHIDLandingPage/LandingPage?iframeSizedToWindow=true&embed=y&:showAppBanner=false&:display_count=no&:showVizHome=no) and 2018 New Mexico state and county population estimates from New Mexico's Indicator-Based Information System (<https://ibis.health.state.nm.us/>), we then calculated the expected number of COVID cases and deaths in each county using these equations:



Expected Cases in County = (County population x Observed Number of COVID cases in state) divided by State population

Expected Deaths in County = (County population x Observed Number of COVID-19 deaths in state) divided by State population

Next, we calculated standardized incidence ratios (SIR) and standardized mortality ratios (SMR) by dividing the observed number of cases and deaths in each county, respectively, by the expected number of cases and deaths.

SIR = observed number of COVID-19 cases divided by expected number of COVID-19 cases.

SMR = observed number of COVID-19 death divided by expected number of COVID-19 deaths.

If the SIR or SMR is greater than one, that indicates that more COVID-19 cases or deaths, respectively, were observed in the county than would be expected based on state-wide rates. If the SIR or SMR is less than one, fewer COVID-19 cases or deaths, respectively, were observed in the county than would be expected based on state-wide rates.

We separately adjusted the SIRs and SMRs for age and race using the age and race distribution of COVID-19 reported by each state (<https://covid19.colorado.gov/data>, <https://cvprovider.nmhealth.org/public-dashboard.html>). These distributions were not publicly available for COVID-19 deaths in New Mexico. We calculated 95% confidence intervals (CI) for the SCR and SMR. Death counts of less than 10 are suppressed in figures and tables.

Colorado Results

Cases of COVID-19: In the five Colorado counties with active oil and gas production sites, the number of observed cumulative cases was higher than expected in three of the counties and lower than expected in two. People aged 20-29 years and Hispanics in Colorado were experiencing a disproportionately greater incidence of COVID-19. Because Colorado county populations differ in age and ethnicity distribution

, we adjusted the results to account for the proportion of COVID-19 vulnerable groups. Although impacts were minor, adjusting these results for race impacted the estimated number of expected cases more than adjusting for age. As shown in , race-adjusted SIRs in Adams, Garfield, and Weld counties exceeded one, indicating higher-than-expected numbers of cumulative COVID-19 cases; those are 1.35 (95% CI 1.33, 1.38), 1.25 (95% CI 1.18, 1.33), and 1.13 (95%CI 1.09, 1.16). In LaPlata and Broomfield counties, race-adjusted SIRs are 0.45 (95% CI 0.40, 0.50) and 0.92 (0.85, 0.98). These rates, which fell at less than one, indicate that the observed number of cumulative COVID cases in these two counties was below the expected numbers based on statewide rates.

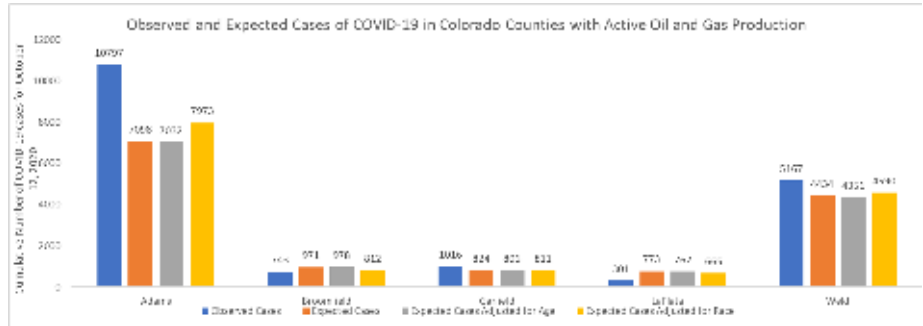


Figure 1

Figure 2

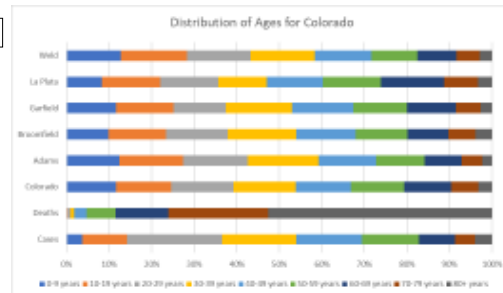
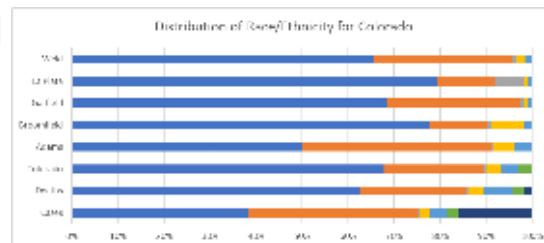


Figure 3



County	SIR (95% CI)	SIR (95% CI) Adjusted for Age	SIR (95% CI) Adjusted for Race
Adams	1.52 (1.49, 1.56)	1.54 (1.51, 1.56)	1.35 (1.33, 1.38)
Broomfield	0.77 (0.71, 0.82)	0.76 (0.71, 0.82)	0.92 (0.85, 0.98)
Garfield	1.23 (1.16, 1.31)	1.26 (1.18, 1.34)	1.25 (1.18, 1.33)
LaPlata	0.39 (0.35, 0.43)	0.40 (0.35, 0.44)	0.45 (0.40, 0.50)
Weld	1.17 (1.13, 1.19)	1.42 (1.38, 1.45)	1.13 (1.09, 1.16)

CI = confidence interval, SIR = Standardized Incidence Ratio

¹Compared to Colorado population

Colorado Results [continued]

Deaths from COVID-19: Interestingly, the number of observed cumulative deaths was higher than expected in the three Colorado counties – Adams, Broomfield, and Weld – located in the Denver Julesburg basin, in the northeastern quadrant of the state, and lower than expected in the counties in the Piceance and San Juan Basins. In Colorado, people 70 years and older were experiencing a disproportionately greater COVID-19 mortality rate.

Adjustment for age impacted the estimated number of expected deaths more than adjustment for race. As shown in Figure 4, age-adjusted SMRs for Adams, Broomfield, and Weld counties exceeded one, indicating that the cumulative number of deaths from COVID-19 was higher than expected. Those SMRs are 1.69 (95%CI 1.48, 1.91), 1.31 (0.89, 1.74), and 1.48 (95% CI 1.25, 1.72). In LaPlata and Garfield counties, age-adjusted SMRs are 0.09 (0,0.21) and 0.26 (0.03, 0.48); those rates, which are less than one, indicate that there were fewer deaths from COVID-19 than expected.

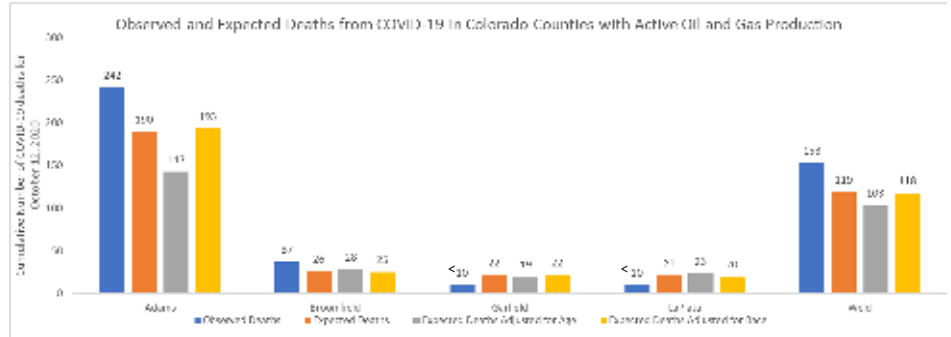


Figure 4

County	SMR (95% CI)	SMR (95% CI) Adjusted for Age	SMR (95% CI) Adjusted for Race
Weld	1.29 (1.09, 1.49)	1.48 (1.25, 1.72)	1.30 (1.09, 1.50)
Garfield	0.23 (0.03, 0.43)	0.26 (0.03, 0.48)	0.23 (0.03, 0.43)
Broomfield	1.42 (0.97, 1.88)	1.31 (0.89, 1.74)	1.47 (1.00, 1.95)
LaPlata	0.10 (0, 0.23)	0.09 (0, 0.21)	0.10 (0, 0.24)
Adams	1.27 (1.11, 1.43)	1.69 (1.48, 1.91)	1.25 (1.09, 1.41)

CI = Confidence Interval SMR = Standardized Mortality Ratio
¹Compared to Colorado population

New Mexico Results

Cases of COVID-19: In the five New Mexico counties with active oil and gas production sites, the number of observed cumulative COVID-19 cases was also higher than expected in three counties and lower than expected in two

. In New Mexico, people aged 20-49 years and Native Americans were experiencing a disproportionately greater incidence of COVID-19

Adjustment for race impacted the number of estimated expected cases more than adjustment for age, particularly in San Juan County which has a large Native American population. As shown in Figure 5, race-adjusted SIRs for Lea, Eddy, and San Juan counties are 1.64 (95% CI 1.56, 1.71), 1.45 (95% CI 1.36, 1.54) and 1.13 (95% CI 1.10, 1.17). These SIRs are greater than one and indicate higher than expected numbers of cumulative COVID-19 cases. In Rio Arriba and Sandoval counties, race-adjusted SIRs are 0.51 (95% CI 0.46, 0.56) and 0.66 (0.63, 0.70). These SIRs are less than one and indicate lower than expected numbers of cumulative COVID-19 cases.

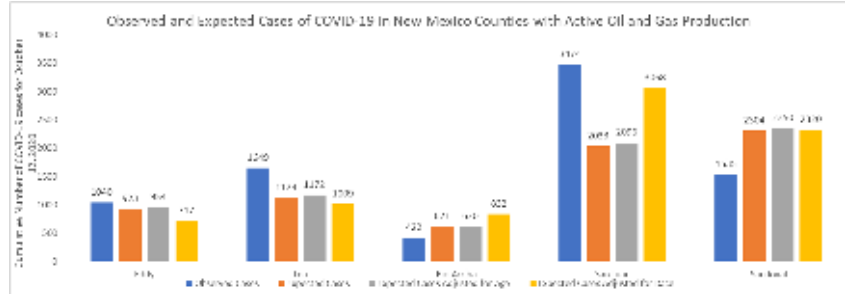


Figure 5

Figure 6

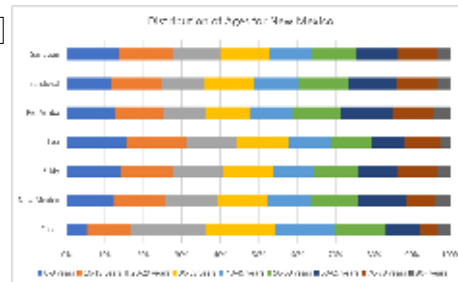
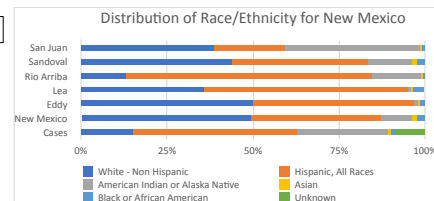


Figure 7



County	SIR (95% CI)	SIR (95% CI) Adjusted for Age	SIR (95% CI) Adjusted for Race
San Juan	1.71 (1.65, 1.77)	1.66 (1.60, 1.71)	1.13 (1.10, 1.17)
Eddy	1.13 (1.06, 1.20)	1.09 (1.02, 1.16)	1.45 (1.36, 1.54)
Lea	1.47 (1.40, 1.54)	1.41 (1.34, 1.48)	1.64 (1.56, 1.71)
Rio Arriba	0.68 (0.62, 0.75)	0.68 (0.62, 0.75)	0.51 (0.46, 0.56)
Sandoval	0.67 (0.63, 0.70)	0.65 (0.62, 0.69)	0.66 (0.63, 0.70)

CI = Confidence Interval SIR = Standardized Incidence Ratio

¹Compared to New Mexico population

New Mexico Results [continued]

Deaths from COVID-19: In New Mexico, the number of observed cumulative deaths was higher than expected in only one county and lower than expected in four counties

. It is likely that adjustment for age and/or race would modify these results. However, age and race distributions for COVID-19 deaths are not publicly available in New Mexico. As shown in [Table 5](#), the unadjusted SMR for San Juan County is 3.62 (95%CI 3.12, 4.12). The unadjusted SMRs for Eddy, Lea, Rio Arriba, and Sandoval counties are 0.63 (95%CI 0.32, 0.94), 0.91 (95%CI 0.57, 1.24), 0.82 (95%CI 0.39, 1.25), and 0.68 (95% CI 0.48, 0.88).

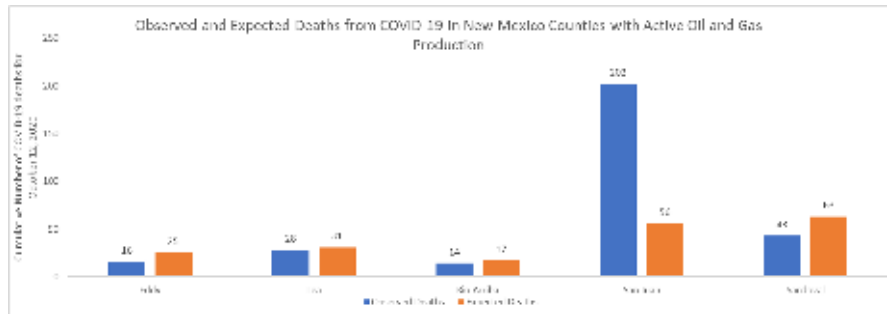
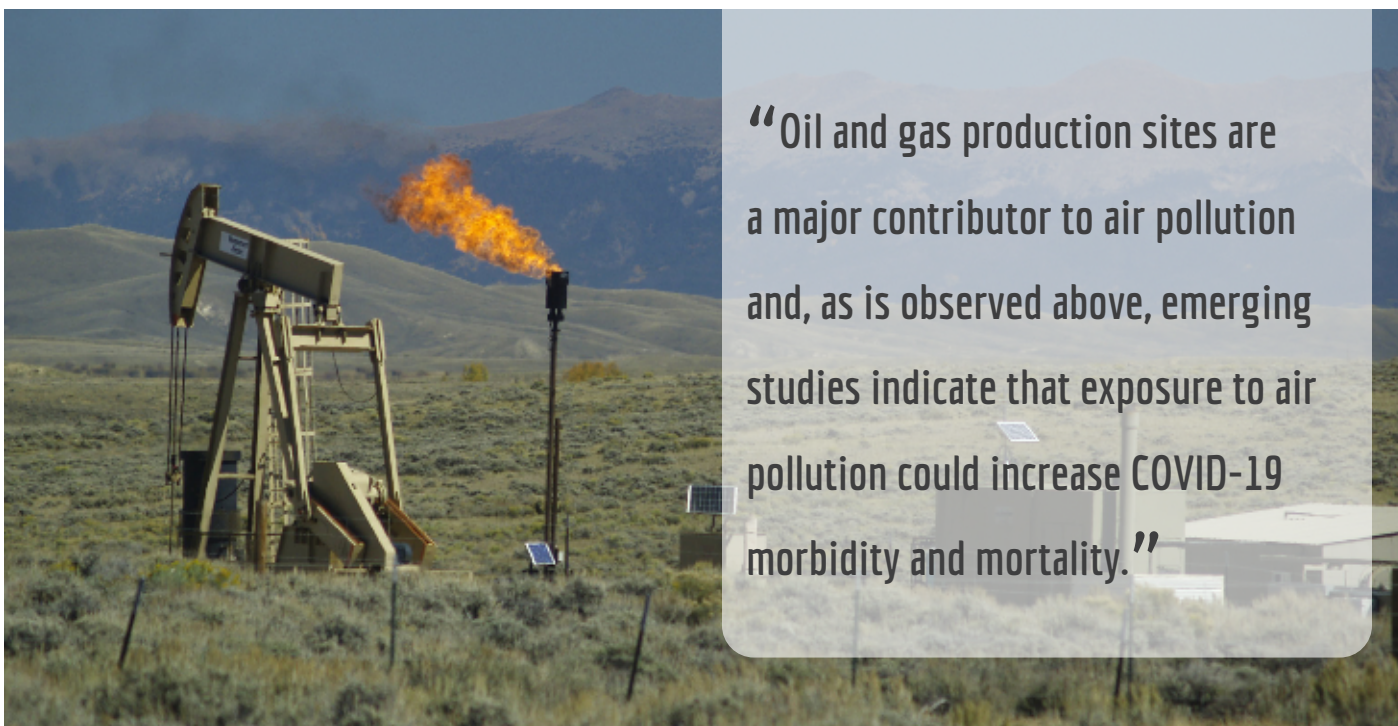


Figure 8

County	SMR (95% CI)
San Juan	3.62 (3.12, 4.12)
Eddy	0.63 (0.32, 0.94)
Lea	0.91 (0.57, 1.24)
Rio Arriba	0.82 (0.39, 1.25)
Sandoval	0.68 (0.48, 0.88)

SMR = Standardized Mortality Ratio

¹Compared to New Mexico population, data for age and race adjustment not publicly available.



“Oil and gas production sites are a major contributor to air pollution and, as is observed above, emerging studies indicate that exposure to air pollution could increase COVID-19 morbidity and mortality.”

These results indicate that the cumulative number of COVID-19 cases and deaths are higher than would be expected in some counties with active oil and gas production sites, but not in others. While these results are inconclusive, the observation that more COVID-19 deaths were observed than expected in the three Colorado counties located in the Denver Julesburg Basin could support hypothesis generation for further study. Those three counties – Adams, Broomfield, and Weld – experienced the bulk of the oil and gas development that occurred in Colorado in 2020. The potential for exposure to air pollutants associated with oil and gas development is highest while the well site is being developed and extraction is taking place (e.g. drilling, hydraulic fracturing, and flowback).^{29,30}

Oil and gas production sites are a major contributor to air pollution³¹ and, as is observed above, emerging studies indicate that exposure to air pollution could increase COVID-19 morbidity and mortality. However, it is not possible in this type of study to isolate the role in COVID-related morbidity and mortality of air pollution from oil and gas sites, relative to other major sources of air pollution. Other major air pollution sources in the counties we evaluated

include wildfires and traffic. For example, numerous hazardous air quality alerts due to particulate matter in wildfire smoke were issued in Garfield, Adams, Broomfield, and Weld counties in the summer and fall of 2020. Traffic is a significant source of both particulate matter and nitrogen dioxide emissions.

Additionally, many factors other than air pollution exposure could influence the transmission and/or severity of COVID-19 in these counties, including compliance with COVID-19 restrictions (e.g. social distancing and mask-wearing) and prevalence of co-morbidities such as asthma, diabetes, and obesity, as well as proportions of high-risk essential worker and residential populations, such as meat-packing workers, prisoners, and nursing home residents. Further investigations using individual-level data on COVID-19 morbidity and mortality and exposures to air pollution from each of these sources would be necessary to determine if air pollution from oil and gas production sites were exacerbating COVID-19. Additionally, co-morbidities, age, vulnerability to COVID-19 exposure, and other individual characteristics would need to be included in future studies.



This study asks whether living in an area with active oil and gas extraction operations increases a person’s risk of getting, or dying from, COVID-19. The question is an important one, yet this study does not pretend to generate definitive answers. Rather, it constitutes only a first step in that inquiry, one that generates hypotheses that we hope will be pursued in future research.

Based on the data that we reviewed, it is unclear whether oil and gas operations are affecting COVID-19 transmission, morbidity, and mortality in Colorado and New Mexico. That being said, evidence is emerging that air pollution increases the risk of getting a respiratory virus like COVID-19 and of experiencing a bad outcome, such as hospitalization or death. For that reason, reducing all sources of air pollution is a good strategy in protecting people from COVID-19. To that end we offer the following recommendations:

- As oil and gas operations add to the cumulative air pollution burden in an airshed,

- Unlike some other air pollution sources, like wildfires, oil and gas pollutant emissions are something that can be controlled in the relatively short term. This makes it appropriate to

related to oil and gas operations.

- to isolate and quantify the role played by oil and gas operations in contributing to nearby residents’ vulnerability to disease and deaths associated with COVID-19. We suggest that individual-level data on COVID-19 exposure, morbidity and mortality as well as co-morbidities, age, and other individual characteristics be among the questions to be explored.

¹Johns Hopkins Coronavirus Resource Center.
<https://coronavirus.jhu.edu>

²Schwartz, J. "Air Pollution and Children's Health." *Pediatrics*. April 2004, 113 (Supplement 3) 1037-1043 https://pediatrics.aappublications.org/content/113/Supplement_3/1037

³World Health Organization. "Ambient air pollution: Health impacts." <https://www.who.int/airpollution/ambient/health-impacts/en/>

⁴Shin, J., et al. "Long-term exposure to ambient air pollutants and mental health status: A nationwide population-based cross-sectional study." *PLoS One*. 2018; 13(4): e0195607. <https://doi.org/10.1371/journal.pone.0195607>

⁵World Health Organization. "Ambient (outdoor) air pollution." https://www.who.int/health-topics/air-pollution#tab=tab_1

⁶Southwest Pennsylvania Environmental Health Project. "Air Pollution and Respiratory Infections: Reviewing the Science." 2020. https://www.environmentalhealthproject.org/sites/default/files/assets/resources/air-pollution-and-respiratory-infections-reviewing-the-science_0.pdf

⁷Centers for Disease Control and Prevention. Coronavirus Disease 2019 (COVID-19). "People with Certain Medical Conditions." Updated November 2, 2020. <https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-with-medical-conditions.html>

⁸Centers for Disease Control, "Symptoms of Coronavirus." <https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html>

⁹Columbia University Irving Medical Center, "Even Mild Cases Can Cause 'COVID-19 Fog.'" September 21, 2020. <https://www.cuimc.columbia.edu/news/even-mild-cases-can-cause-covid-19-fog>.

¹⁰Frontera, A. et al. "Severe air pollution links to higher mortality in COVID-19 patients: The "double hit" hypothesis." *Journal of Infection*. Volume 81, Issue 2, August 2020, Pages 255-259. <https://doi.org/10.1016/j.jinf.2020.05.031>

¹¹Zhu, Y., et al. "Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China." *Science of The Total Environment*. Volume 727, July 20, 2020, 138704. <https://doi.org/10.1016/j.scitotenv.2020.138704>

¹²Wu, X., et al. "Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study." *Harvard T.H. Chan School of Public Health*. April 27, 2020. <https://doi.org/10.1101/2020.04.05.20054502>

¹³Austin, W., et al. "COVID-19 Mortality and Contemporaneous Air Pollution." Georgia State University Andrew Young School of Policy Studies, International Center for Public Policy Working Paper 20-16 October 2020. <https://icepp.gsu.edu/files/2020/10/paper2016.pdf>

¹⁴Golden, S. "Coronavirus in African Americans and Other People of Color." *Johns Hopkins Medicine*. <https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus/covid19-racial-disparities>

¹⁵Grinshpun, M. "COVID-19 Teaches Us Lessons About Air Pollution, Environmental Justice, and Climate Change." Boston University Institute for Sustainable Energy. <http://www.bu.edu/ise/2020/05/19/covid-19-teaches-us-lessons-about-air-pollution-environmental-justice-and-climate-change/>

¹⁶McKenzie LM, Allshouse WB, Burke T, Blair BD, Adgate JL. "Population Size, Growth, and Environmental Justice Near Oil and Gas Wells in Colorado." *Environmental Science & Technology*. 2016;50(21):11471-11480. PMID 27689723. <https://pubs.acs.org/doi/10.1021/acs.est.6b04391>

¹⁷Czolowski ED, Santoro RL, Srebotnjak T, Shonkoff SB. Toward Consistent Methodology to Quantify Populations in Proximity to Oil and Gas Development: A National Spatial Analysis and Review. *Environ Health Perspect*. 2017;125(8):086004. PMID 28858829 <https://doi.org/10.1289/EHP1535>

¹⁸Allshouse, W.B., et al, "Community Noise and Air Pollution Exposure During the Development of a Multi-Well Oil and Gas Pad." *Environ Sci Technol* 2019 Jun 18;53(12):7126-7135. <https://pubs.acs.org/doi/10.1021/acs.est.9b00052>

¹⁹Helmig, D., 2020. Air quality impacts from oil and natural gas development in Colorado. *Elem Sci Anth*, 8(1), p.4. DOI: <http://doi.org/10.1525/elementa.398>

²⁰United States Environmental Protection Agency. "Health Effects of Ozone Pollution." <https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution>

²¹Helmig, D., 2020. "Air quality impacts from oil and natural gas development in Colorado." *Elem Sci Anth*, 8(1), p.4. DOI: <http://doi.org/10.1525/elementa.398>

²²McKenzie LM, et al, "Human health risk assessment of air emissions from development of unconventional natural gas resources," *Sci Total Environ* (2012), <https://doi.org/10.1016/j.scitotenv.2012.02.018>

²³McKenzie, LM, et al. "Ambient Nonmethane Hydrocarbon Levels Along Colorado's Northern Front Range: Acute and Chronic Health Risks." *Environ Sci Technol*. 2018 Apr 17;52(8):4514-4525. doi: [10.1021/acs.est.7b05983](https://doi.org/10.1021/acs.est.7b05983). Epub 2018 Apr 9.

²⁴Chris Holder, John Hader, Raga Avanasani, Tao Hong, Ed Carr, Bill Mendez, Jessica Wignall, Graham Glen, Belle Guelden & Yihua Wei (2019) "Evaluating potential human health risks from modeled inhalation exposures to volatile organic compounds emitted from oil and gas operations," *Journal of the Air & Waste Management Association*, 69:12, 1503-1524, DOI: <https://doi.org/10.1080/10962247.2019.1680459>

²⁵Fann N, Baker KR, Chan EAW, et al. "Assessing Human Health PM2.5 and Ozone Impacts from U.S. Oil and Natural Gas Sector Emissions in 2025." *Environmental Science & Technology*. 2018;52(15):8095-8103. PMID 30004688 <https://doi.org/10.1021/acs.est.8b02050>

²⁶Russo, P.N. & Carpenter, D.O., Institute for Health and the Environment, University at Albany. "Health Effects Associated with Stack Chemical Emissions from NYS Natural Gas Compressor Stations: 2008-2014." October 12, 2017. https://www.albany.edu/about/assets/Complete_report.pdf

²⁷Physicians for Social Responsibility and Concerned Health Professionals of New York. "Compendium of Scientific, Medical, and Media Findings Demonstrating the Risks and Harms of Fracking (Unconventional Gas and Oil Extraction) — Sixth Edition." June 2019. <https://www.psr.org/wp-content/uploads/2019/06/compendium-6.pdf>

²⁸Colorado Oil and Gas Dashboard. <https://cogcc.state.co.us/DAD.html> Accessed October 30, 2020

²⁹Chris Holder, John Hader, Raga Avanasani, Tao Hong, Ed Carr, Bill Mendez, Jessica Wignall, Graham Glen, Belle Guelden & Yihua Wei (2019) "Evaluating potential human health risks from modeled inhalation exposures to volatile organic compounds emitted from oil and gas operations," *Journal of the Air & Waste Management Association*, 69:12, 1503-1524, DOI: 10.1080/10962247.2019.1680459

³⁰Allshouse, W.B., et al, "Community Noise and Air Pollution Exposure During the Development of a Multi-Well Oil and Gas Pad." *Environ Sci Technol* 2019 Jun 18;53(12):7126-7135. <https://pubs.acs.org/doi/10.1021/acs.est.9b00052>

³¹Helmig, D., 2020. Air quality impacts from oil and natural gas development in Colorado. *Elem Sci Anth*, 8(1), p.4. DOI: <http://doi.org/10.1525/elementa.398>





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