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Abstract:
COVID-19 has exacted a severe toll on the United States population’s physical and mental health and its effects have been felt most severely among people of color and low socioeconomic status. Using illustrative case studies, this commentary argues that in addition to COVID-19 health disparities created by psychosocial stressors such as the inability to socially distance and access quality healthcare, environmental justice communities have the additional burden of disproportionate exposure to toxic contaminants that contribute to their higher risk of COVID-19. Environmental contaminants including heavy metals and persistent organic pollutants found contaminating their nearby environments can alter the immune response, produce an inflammatory response, and induce systemic adverse health effects that, alongside social stressors, create the “perfect storm” in environmental justice communities for COVID-19.

Keywords:
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## Cover Page Footnote

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## ABSTRACT

COVID-19 has exacted a severe toll on the United States population's physical and mental health and its effects have been felt most severely among people of color and low socioeconomic status. Using illustrative case studies, this commentary argues that in addition to COVID-19 health disparities created by psychosocial stressors such as the inability to socially distance and access quality healthcare, environmental justice communities have the additional burden of disproportionate exposure to toxic contaminants that contribute to their higher risk of COVID-19. Environmental contaminants including heavy metals and persistent organic pollutants found contaminating their nearby environments can alter the immune response, produce an inflammatory response, and induce systemic adverse health effects that, alongside social stressors, create the "perfect storm" in environmental justice communities for COVID-19.

**Keywords:** Environmental justice; COVID-19; health disparities; environmental contamination

## INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) pandemic caused by the spread of the novel coronavirus has exacted a severe toll on the United States population's physical and mental health, as well as its overall social and economic vitality. As of January 3, 2021, the U.S. had over 20.5 million confirmed cases of COVID-19, over 351,000 deaths, and the pandemic has forced one in four workers to apply for unemployment benefits (Dong, Du, & Gardner, 2020; Tappe, 2020). Rather than being "the great equalizer" due to universal lack of immunity, data have shown that the burden of COVID-19 has been disproportionately felt by racial/ethnic minority and low-income communities (Laurencin & McClinton, 2020; Mein, 2020; Webb Hooper, Nápoles, & Pérez-Stable, 2020). These health disparities are due to a variety of psychosocial stressors stemming from structural inequalities that place individuals of color and/or low socioeconomic status at greater risk for the contraction and increased severity of COVID-19. However, environmental justice (EJ) communities, "poor and minority communities that bear a disproportionate burden of environmental health risk," not only face these psychosocial stressors, but are also unjustly exposed to disproportionate levels of environmental contaminants (Prochaska et al., 2014). According to the U.S. Environmental Protection Agency, environmental justice is "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" ("Environmental Justice," 2020). EJ communities' physical, social, and chemical environmental stressors place them at greater risk for severe adverse occurrences of COVID-19. Using case studies, we argue that in addition to COVID-19 health disparities created by psychosocial stressors, EJ communities have the additional burden of disproportionate exposure to toxic contaminants that could contribute to their higher risk of COVID-19 contraction and increased severity.

## Social and Environmental Inequalities

Public health researchers have studied the complex socioecological pathways through which COVID-19 has unduly impacted low-income communities of color throughout the U.S. The vast majority of those deemed essential workers beyond the health care sector and who work without paid sick leave, including those employed at factories, farms, grocery stores, delivery services, restaurants, and hospitals, identify as Black or Latinx (Lancet, 2020). Their reliance on public transportation to commute to work, alongside crowded living conditions, create additional opportunities for virus transmission (Mein, 2020; Webb Hooper et al., 2020). Disadvantaged neighborhoods are often characterized by exposure to elevated levels of environmental contamination and poor indoor air quality, as well as limited access to affordable, nutritious food that bolsters the immune response to fight viral infections, including COVID-19 (Yancy, 2020).

Those filing for first-time unemployment, most of whom are low-income, are also losing employer-based health insurance for themselves and their families (Mein, 2020). Millions of others, especially undocumented workers in rural industries, remain uninsured and lack available testing and treatment facilities to obtain adequate and timely COVID-19 identification and follow-up care (Mein, 2020; Schmitt-Grohé, Teoh, & Uribe, 2020). In rural areas such as Native American reservations, most of which are located within three miles of a toxic Superfund site, members of households without indoor plumbing are unable to adhere to the scrupulous hygiene practices recommended to prevent and limit the spread of COVID-19 (Rodriguez-Lonebear, Barceló, Akee, & Carroll, 2020). Indian Health Service facilities have an insufficient number of hospital beds and intensive care units to respond to outbreaks and are located a far distance away from Tribal members' residences (Kakol, Upson, & Sood, 2020). In addition, the cumulative stress induced by persistent external stressors such as interpersonal and institutional discrimination takes a physical toll on the body and causes premature aging, or "weathering" (Chowkwanyun & Reed, 2020). This could partially explain the elevated prevalence of co-morbidities associated with severe COVID-19 (e.g., diabetes, obesity, hypertension, coronary heart disease, chronic obstructive pulmonary disease, and kidney disease) among racial/ethnic minorities and those of low socioeconomic status (Mein, 2020).

Many studies have addressed the aggregated risk of social determinants of health and environmental exposures (Prochaska et al., 2014). Adding to the pressure posed by these social inequities are environmental factors such as poor air and water quality that plague these marginalized communities and contribute extensively to their vulnerability and disproportionate disease burden. Environmental health disparities exist when communities exposed to a combination of poor environmental quality and social inequities have more sickness and disease than wealthier, less polluted communities, leading to the "perfect storm" for infectious disease pandemics, including COVID-19. Several studies have documented the association between exposure to criteria air pollutants, including particulate matter (PM), sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), volatile organic compounds (VOCs), and carbon monoxide (CO) and a greater incidence of COVID-19, particularly in densely populated urban areas with high proportions of African Americans (Bashir et al., 2020; Brandt, Beck, & Mersha, 2020; Wu, Nethery, Sabath, Braun, & Dominici, 2020).

Toxicant Burdens in Relation to COVID-19

EJ communities are disproportionately exposed to a variety of environmental contaminants released by current and former industrial and military activities, concentrated animal feeding operations, hazardous waste sites/Superfund sites, and mining operations. These toxic and carcinogenic compounds include (among other chemicals) heavy metals such as uranium, mercury, lead, cadmium, and arsenic, and persistent organic pollutants including polychlorinated biphenyls (PCBs), pesticides, and polycyclic aromatic hydrocarbons (PAHs). Many of these compounds have endocrine disrupting properties and can also adversely impact the immune response, especially against infections (De Coster & van Larebeke, 2012; Kavlock et al., 1996).

Environmental exposure to PCBs, for example, is associated with various diseases including myocardial infarction, hypertension, obesity, and stroke (Wahlang, Petriello, Perkins, Shen, & Hennig, 2016). PCBs, endocrine disrupters present in air, water, soil and products manufactured before they were banned in the U.S. in 1979, are persistent in the environment, easily absorbed by the body, and stored for many years in fatty tissue, which explains health effects observed long after exposure. Certain types of PCBs can also induce an inflammatory response through the activation of pro-inflammatory factors that aid in the over-production of cytokines (Eske et al., 2014). This is especially important because severe cases of COVID-19 are characterized by a "cytokine storm," an uncontrollable inflammatory response due to an overproduction of specific cytokines. Thus, lifetime exposure to PCBs could increase the probability of a "cytokine storm" in the event of a symptomatic COVID-19 diagnosis.

Studies have also shown that exposure to another class of environmental contaminants often found in waste sites nearby EJ communities, organophosphate pesticides, are important risk factors for developing metabolic diseases, including diabetes and immune disorders (Lee & Choi, 2020; Starling et al., 2014). For example, ingestion of chlorpyrifos, a family of organophosphates, increases inflammatory mediators (such as interleukin [IL]-1ß, tumor necrosis factor [TNF]-α and monocyte chemoattractant protein [MCP]-1) in the ileum and colon of mice (Liang et al., 2019).

Such inflammation diminishes the integrity of the intestine, leading to insulin resistance and obesity (Liang et al., 2019). Also, like many other organophosphate pesticides, chlorpyrifos interferes with specific immunological functions.

Heavy metal exposure (e.g., cadmium, arsenic, lead) has been linked to a wide range of health effects, including lung and heart disease, cancer, and/or immune dysfunction (Rehman, Fatima, Waheed, & Akash, 2018). For example, chronic low-dose exposure to inorganic arsenic severely compromises the immune response to influenza A and increases morbidity in mice. More specifically, arsenic-exposed mice demonstrate altered cellular responses, decreased cytokine production, and increased viral load (Kozul, Ely, Enelow, & Hamilton, 2009). As arsenic can reduce immune responses to influenza A and increase morbidity in mice, it is feasible that individuals exposed chronically to arsenic-containing contamination could elicit similar immunocompromise and increased risk of other respiratory infections, like COVID-19. Other heavy metals, such as uranium in small dust particles from mining sites, can deeply penetrate the lungs, leading to pulmonary inflammation (Hettiarachchi, Paul, Cadol, Frey, & Rubasinghege, 2019). In addition, cadmium can alter synthesis and expression of some pro-inflammatory cytokines (Olszowski, Baranowska-Bosiacka, Gutowska, & Chlubek, 2012). Various studies have highlighted the ability of cadmium to modulate the innate, adaptive and mucosal immune responses in relations to the release of chemokine, gene expression, and susceptibility to microbial infections (Hossein-Khannazer et al., 2020). The adverse health consequences that arise from heavy metal exposure can thus leave EJ communities at higher risk of severe respiratory illnesses, including COVID-19.

In addition, other toxicants present in contaminated environments, like phthalates used in plastics, can affect enzymes involved in endocrine system functioning at numerous levels, producing hormonal imbalances that lead to various diseases and preclinical immune problems. Given the reported high prevalence of obese (63.5%) and diabetic (24.9%) patients who go on to need invasive mechanical ventilation from COVID-19, it is critical to identify the presence of such endocrine-disrupting chemical contaminants and understand their role in this capacity (Caussy, Wallet, Laville, & Disse, 2020; Yan et al., 2020).

The aforementioned chemicals are but only a few compounds commonly found in waste sites around EJ communities. These are meant only as a few examples of how chemical contaminants can exacerbate health outcomes in a "perfect storm" scenario. Many of the aforementioned toxicants can also induce systemic health problems and co-morbidities (affecting the cardiovascular, respiratory, and metabolic systems) placing those exposed at greater risk of contracting infectious diseases such as COVID-19 and therefore experiencing far more severe cases of the disease. Thus, there is a critical need for additional research to examine the emerging relationships between environmental contaminants and their association with COVID-19 outcomes in a diverse array of urban, rural, and indigenous EJ community contexts. The few examples provided below are not meant to be a complete list of environmentally-impacted communities, but only to provide illustrative examples of some diverse communities who bear increased and disproportionate exposure to environmental contaminants and thus face increased vulnerabilities and potentially higher risks of COVID-19.

Rural EJ Communities

Rural EJ communities throughout the U.S. "often live adjacent to a variety of point source polluters, ranging from confined animal feeding operations to under-regulated small businesses, illicit methamphetamine laboratories, or both" (Butterfield, Postma, & team, 2009). This is largely due to residential proximity to agricultural property with heavy pesticide use, relaxed zoning regulations, and lower property values (Butterfield et al., 2009). "Chemical Corridor," also known as "Cancer Alley," is the notorious 85-mile stretch between Baton Rouge and New Orleans, Louisiana along the Mississippi River that hosts over 140 chemical, fertilizer, and plastics factories, as well as oil refineries that account for nearly a quarter of the nation's petrochemical production. The name Cancer Alley is derived from both statistical evidence and anecdotal accounts of elevated rates of cancer and other chronic conditions in this area, including skin rashes, respiratory ailments, reproductive problems, and headaches, all of which have "given the region a notorious reputation for illness" (Davies, 2018; Singer, 2011). The region is made up of rural parishes that are primarily home to low-income Black communities who trace their lineage to slavery (Davies, 2018). For example, St. John the Baptist Parish, which is 65% non-white with a median household income of $54,821, has a death rate of 22.1 per 10,000 and is "consistently ranked among the top 30 U.S. counties with the highest COVID-19 death rates" (Jervis & Gomez, 2020). Elevated rates of COVID-19 documented among residents of Chemical Corridor are likely driven, in part, by their disproportionate exposure to environmental contaminants including ammonia, sulfuric acid, and chloroprene from polluting industries that are predominantly located in low-income, African American areas (Blodgett, 2006; Jervis & Gomez, 2020; Terrell & James, 2020).

Native American EJ Communities

According to the U.S. Centers for Disease Control and Prevention, the COVID-19 incidence and mortality (55.8 per 100,000) rates in Native Americans and Alaska Natives are 3.5 and 1.8 times those measured in Whites, respectively (Arrazola et al., 2020). Tribal lands are "attractive locations for extractive purposes to corporations who do not want to be indebted to the same level of environmental regulation and oversight as they would be in areas solely under state jurisdiction" (Meltzer, Watkins, Vieira, Zelikoff, & Boden-Albala, 2020). These practices were permitted to proceed due to the U.S. government's abrogation of treaty rights that granted Tribes sovereignty over their land upon discovering the vast wealth of natural resources that could be extracted for economic gain (Lewis, Hoover, & MacKenzie, 2017). In addition, Tribal lands house 25% of the 1,322 Superfund sites in the United States, not including "orphan" waste sites not listed on the National Priority List (Hansen, 2014). Today, there are over 1,100 abandoned mines, milling sites, and waste piles scattered across over 50% of Navajo Nation chapters. These sites are not clearly demarcated nor have been adequately remediated, which has resulted in the leaching of uranium into unregulated wells that supply water to those homes without indoor plumbing (Charley, Dawson, Madsen, & Spykerman, 2004; Corlin et al., 2016). Over one-third of Navajo residents "live without electricity, paved roads, cellphone service, landlines, safe housing, or other essentials of modern life" (Linn, 2018), and roughly 77% are food insecure (Pardilla, Prasad, Suratkar, & Gittelsohn, 2014). The high prevalence of COVID-19 currently observed among younger Navajo individuals could be partially reflective of transgenerational uranium and mixed metal exposures and their potential adverse health effects that were demonstrated in the Navajo Birth Cohort Study, the largest birth cohort study ever carried out on the Navajo Nation ("COVID-19 in New Mexico," 2020; Dooley, 2020; Erdei et al., 2019; Lewis et al., 2015).

Urban EJ Communities

Although most hazardous waste sites are located in rural areas, toxic release and transfer sites tend to be located near large population centers, disproportionately in low-income and minority neighborhoods that are residentially segregated due to discriminatory zoning and housing policies and economic divestment (Harner, Warner, Pierce, & Huber, 2002). These communities also tend to be in closer proximity to urban "waste sites, disposal facilities, transfer storage, incinerators, refineries, and other contaminating industries, known traditionally as locally undesirable land uses" (Anguelovski, 2016). For example, the largest New York City Housing Authority (NYCHA) properties in Gowanus and Red Hook, Brooklyn are located a mere several blocks away from the Gowanus Canal Superfund site contaminated with a combination of household waste, industrial effluent, and storm water runoff containing PAHs, PCBs, pesticides, toxic heavy metals, and VOCs that have permanently contaminated the sediment. Not unexpectedly, the COVID-19 fatality rate in NYCHA developments was over 19% in May 2020, twice that of New York City's at the time (Cruz, 2020). South Brooklyn's NYCHA residents also consistently complain of asthma, cardiomyopathy, renal failure, as well as contaminated drinking water, household lead paint, asbestos, and mold infestations, all of which could compromise their immune response against infectious diseases, including COVID-19 (Wong, 2019).

## CONCLUSION

Exposures to environmental contaminants, in combination with the psychosocial stressors associated with marginalized identities of racial/ethnic minority and low socioeconomic status, render EJ communities vulnerable to and highly impacted by the COVID-19 pandemic. A conceptual shift beyond traditional environmental health is critical to understanding the dynamics of environmental exposure and how it impacts members of already marginalized neighborhoods who are at greater risk. We believe it is imperative that additional research explore, in tandem, the epidemiological and toxicological mechanisms through which disproportionate exposure to environmental contaminants could place members of EJ communities at greater risk of COVID-19 and place them at disadvantage for experiencing poorer infection outcomes and greater severity of this disease. Taken together, epidemiological, toxicological, and public health evidence should serve as a call to action for urgent, multidisciplinary policymaking to protect EJ communities' health and wellbeing during the COVID-19 pandemic and beyond.

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## REFERENCES

Anguelovski, I. (2016). From Toxic Sites to Parks as (Green) LULUs? New Challenges of Inequity, Privilege, Gentrification, and Exclusion for Urban Environmental Justice. *Journal of Planning Literature, 31*(1), 23-36. doi:10.1177/0885412215610491

Arrazola, J., Masiello, M. M., Joshi, S., Dominguez, A. E., Poel, A., Wilkie, C. M., . . . Landen, M. (2020). COVID-19 Mortality Among American Indian and Alaska Native Persons - 14 States, January-June 2020. *MMWR Morb Mortal Wkly Rep, 69*(49), 1853-1856. doi:10.15585/mmwr.mm6949a3

Bashir, M. F., Ma, B. J., Bilal, Komal, B., Bashir, M. A., Farooq, T. H., . . . Bashir, M. (2020). Correlation between environmental pollution indicators and COVID-19 pandemic: A brief study in Californian context. *Environ Res, 187*, 109652. doi:10.1016/j.envres.2020.109652

Blodgett, A. D. (2006). An Analysis of Pollution and Community Advocacy in 'Cancer Alley': Setting an Example for the Environmental Justice Movement in St James Parish, Louisiana. *Local Environment, 11*(6), 647-661. doi:10.1080/13549830600853700

Brandt, E. B., Beck, A. F., & Mersha, T. B. (2020). Air pollution, racial disparities, and COVID-19 mortality. *The Journal of allergy and clinical immunology*, S0091-6749(0020)30632-30631. doi:10.1016/j.jaci.2020.04.035

Butterfield, P., Postma, J., & team, t. E. r. (2009). The TERRA Framework: Conceptualizing Rural Environmental Health Inequities Through an Environmental Justice Lens. *Advances in Nursing Science, 32*(2), 107-117. doi:10.1097/ANS.0b013e3181a3ae93

Caussy, C., Wallet, F., Laville, M., & Disse, E. (2020). Obesity is Associated with Severe Forms of COVID-19. *Obesity (Silver Spring)*. doi:10.1002/oby.22842

Charley, P. H., Dawson, S. E., Madsen, G. E., & Spykerman, B. R. (2004). Navajo Uranium Education Programs: The Search for Environmental Justice. *Applied Environmental Education & Communication, 3*(2), 101-108. doi:10.1080/15330150490444241

Chowkwanyun, M., & Reed, A. L. (2020). Racial Health Disparities and Covid-19 — Caution and Context. *New England Journal of Medicine*. doi:10.1056/NEJMp2012910

Corlin, L., Rock, T., Cordova, J., Woodin, M., Durant, J. L., Gute, D. M., . . . Brugge, D. (2016). Health Effects and Environmental Justice Concerns of Exposure to Uranium in Drinking Water. *Current Environmental Health Reports, 3*(4), 434-442. doi:10.1007/s40572-016-0114-z

COVID-19 in New Mexico. (2020). Retrieved from https://cvprovider.nmhealth.org/public-dashboard.html

Cruz, D. (2020, May 20). Map: COVID-19 Death Rate In NYCHA Developments Far Outpaces That Of NYC. Retrieved from https://gothamist.com/news/map-covid-19-death-rate-nycha-developments-far-outpaces-nyc

Davies, T. (2018). Toxic Space and Time: Slow Violence, Necropolitics, and Petrochemical Pollution. *Annals of the American Association of Geographers, 108*(6), 1537-1553. doi:10.1080/24694452.2018.1470924

De Coster, S., & van Larebeke, N. (2012). Endocrine-disrupting chemicals: associated disorders and mechanisms of action. *J Environ Public Health, 2012*, 713696. doi:10.1155/2012/713696

Dong, E., Du, H., & Gardner, L. (2020). An interactive web-based dashboard to track COVID-19 in real time. *The Lancet Infectious Diseases, 20*(5), 533-534. doi:10.1016/S1473-3099(20)30120-1

Dooley, S. (2020, July 8). Coronavirus Is Attacking the Navajo 'because We Have Built the Perfect Human for It to Invade'. *Scientific American*. Retrieved from https://www.scientificamerican.com/article/coronavirus-is-attacking-the-navajo-because-we-have-built-the-perfect-human-for-it-to-invade/

Environmental Justice. (2020). Retrieved from https://www.epa.gov/environmentaljustice

Erdei, E., Shuey, C., Pacheco, B., Cajero, M., Lewis, J., & Rubin, R. L. (2019). Elevated autoimmunity in residents living near abandoned uranium mine sites on the Navajo Nation. *J Autoimmun, 99*, 15-23. doi:10.1016/j.jaut.2019.01.006

Eske, K., Newsome, B., Han, S. G., Murphy, M., Bhattacharyya, D., & Hennig, B. (2014). PCB 77 dechlorination products modulate pro-inflammatory events in vascular endothelial cells. *Environmental science and pollution research international, 21*(10), 6354-6364. doi:10.1007/s11356-013-1591-3

Hansen, T. (2014). Kill the Land, Kill the People: There Are 532 Superfund Sites in Indian Country! *Indian Country Today*. Retrieved from https://indiancountrytoday.com/archive/kill-the-land-kill-the-people-there-are-532-superfund-sites-in-indian-country-LpCDfEqzlkGEnzyFxHYnJA

Harner, J., Warner, K., Pierce, J., & Huber, T. (2002). Urban Environmental Justice Indices. *The Professional Geographer, 54*(3), 318-331. doi:10.1111/0033-0124.00333

Hettiarachchi, E., Paul, S., Cadol, D., Frey, B., & Rubasinghege, G. (2019). Mineralogy Controlled Dissolution of Uranium from Airborne Dust in Simulated Lung Fluids (SLFs) and Possible Health Implications. *Environmental Science & Technology Letters, 6*(2), 62-67. doi:10.1021/acs.estlett.8b00557

Hossein-Khannazer, N., Azizi, G., Eslami, S., Alhassan Mohammed, H., Fayyaz, F., Hosseinzadeh, R., . . . Noorisepehr, M. (2020). The effects of cadmium exposure in the induction of inflammation. *Immunopharmacol Immunotoxicol, 42*(1), 1-8. doi:10.1080/08923973.2019.1697284

Jervis, R., & Gomez, A. (2020, December 8). Racism turned their neighborhood into 'Cancer Alley.' Now they're dying from COVID-19. Retrieved from https://www.usatoday.com/in-depth/news/nation/2020/10/12/covid-racism-kills-black-americans-living-near-toxic-plants/3498180001/

Kakol, M., Upson, D., & Sood, A. (2020). Susceptibility of Southwestern American Indian Tribes to Coronavirus Disease 2019 (COVID-19). *The Journal of rural health : official journal of the American Rural Health Association and the National Rural Health Care Association*, 10.1111/jrh.12451. doi:10.1111/jrh.12451

Kavlock, R. J., Daston, G. P., DeRosa, C., Fenner-Crisp, P., Gray, L. E., Kaattari, S., . . . Tilson, H. A. (1996). Research needs for the risk assessment of health and environmental effects of endocrine disruptors: a report of the U.S. EPA-sponsored workshop. *Environ Health Perspect, 104 Suppl 4*(Suppl 4), 715-740. doi:10.1289/ehp.96104s4715

Kozul, C. D., Ely, K. H., Enelow, R. I., & Hamilton, J. W. (2009). Low-dose arsenic compromises the immune response to influenza A infection in vivo. *Environ Health Perspect, 117*(9), 1441-1447. doi:10.1289/ehp.0900911

Lancet. (2020). The plight of essential workers during the COVID-19 pandemic. *Lancet, 395*(10237), 1587. doi:10.1016/s0140-6736(20)31200-9

Laurencin, C. T., & McClinton, A. (2020). The COVID-19 pandemic: a call to action to identify and address racial and ethnic disparities. *Journal of Racial and Ethnic Health Disparities*, 1-5.

Lee, G.-H., & Choi, K.-C. (2020). Adverse effects of pesticides on the functions of immune system. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, 235*, 108789. doi:https://doi.org/10.1016/j.cbpc.2020.108789

Lewis, J., Gonzales, M., Burnette, C., Benally, M., Seanez, P., Shuey, C., . . . Nez, S. (2015). Environmental exposures to metals in Native communities and implications for child development: basis for the Navajo birth cohort study. *J Soc Work Disabil Rehabil, 14*(3-4), 245-269. doi:10.1080/1536710X.2015.1068261

Lewis, J., Hoover, J., & MacKenzie, D. (2017). Mining and Environmental Health Disparities in Native American Communities. *Curr Environ Health Rep, 4*(2), 130-141. doi:10.1007/s40572-017-0140-5

Liang, Y., Zhan, J., Liu, D., Luo, M., Han, J., Liu, X., . . . Wang, P. (2019). Organophosphorus pesticide chlorpyrifos intake promotes obesity and insulin resistance through impacting gut and gut microbiota. *Microbiome, 7*(1), 19. doi:10.1186/s40168-019-0635-4

Linn, A. (2018). A forgotten health crisis in Navajo lands. Retrieved from https://www.centerforhealthjournalism.org/2018/07/08/forgotten-health-crisis-navajo-lands

Mein, S. A. (2020). COVID-19 and Health Disparities: the Reality of "the Great Equalizer". *Journal of general internal medicine*, 1-2. doi:10.1007/s11606-020-05880-5

Meltzer, G. Y., Watkins, B.-X., Vieira, D., Zelikoff, J. T., & Boden-Albala, B. (2020). A Systematic Review of Environmental Health Outcomes in Selected American Indian and Alaska Native Populations. *Journal of Racial and Ethnic Health Disparities*. doi:10.1007/s40615-020-00700-2

Olszowski, T., Baranowska-Bosiacka, I., Gutowska, I., & Chlubek, D. (2012). Pro-inflammatory properties of cadmium. *Acta Biochim Pol, 59*(4), 475-482.

Pardilla, M., Prasad, D., Suratkar, S., & Gittelsohn, J. (2014). High levels of household food insecurity on the Navajo Nation. *Public Health Nutrition, 17*(1), 58-65. doi:10.1017/S1368980012005630

Prochaska, J. D., Nolen, A. B., Kelley, H., Sexton, K., Linder, S. H., & Sullivan, J. (2014). Social Determinants of Health in Environmental Justice Communities: Examining Cumulative Risk in Terms of Environmental Exposures and Social Determinants of Health. *Human and Ecological Risk Assessment: An International Journal, 20*(4), 980-994. doi:10.1080/10807039.2013.805957

Rehman, K., Fatima, F., Waheed, I., & Akash, M. S. H. (2018). Prevalence of exposure of heavy metals and their impact on health consequences. *J Cell Biochem, 119*(1), 157-184. doi:10.1002/jcb.26234

Rodriguez-Lonebear, D., Barceló, N. E., Akee, R., & Carroll, S. R. (2020). American Indian Reservations and COVID-19: Correlates of Early Infection Rates in the Pandemic. *Journal of Public Health Management and Practice, 26*(4), 371-377. doi:10.1097/phh.0000000000001206

Schmitt-Grohé, S., Teoh, K., & Uribe, M. (2020). *Covid-19: Testing Inequality in New York City* (0898-2937). Retrieved from

Singer, M. (2011). Down Cancer Alley: The Lived Experience of Health and Environmental Suffering in Louisiana's Chemical Corridor. *Medical Anthropology Quarterly, 25*(2), 141-163. doi:10.1111/j.1548-1387.2011.01154.x

Starling, A. P., Umbach, D. M., Kamel, F., Long, S., Sandler, D. P., & Hoppin, J. A. (2014). Pesticide use and incident diabetes among wives of farmers in the Agricultural Health

Study. *Occupational and Environmental Medicine, 71*(9), 629-635. doi:10.1136/oemed-2013-101659

Tappe, A. (2020). 1 in 4 American workers have filed for unemployment benefits during the pandemic. Retrieved from https://www.cnn.com/2020/05/28/economy/unemployment-benefits-coronavirus/index.html

Terrell, K., & James, W. (2020). *Air Pollution and COVID-19: A Double Whammy for African American and Impoverished Communities in Cancer Alley*. Tulane University. Retrieved from https://law.tulane.edu/sites/law.tulane.edu/files/Files/Terrell%20-%20COVID-19%20-%20PM%202.5%20Louisiana%202020-5-14%20WEB%20VERSION.pdf

Wahlang, B., Petriello, M. C., Perkins, J. T., Shen, S., & Hennig, B. (2016). Polychlorinated biphenyl exposure alters the expression profile of microRNAs associated with vascular diseases. *Toxicol In Vitro, 35*, 180-187. doi:10.1016/j.tiv.2016.06.001

Webb Hooper, M., Nápoles, A. M., & Pérez-Stable, E. J. (2020). COVID-19 and Racial/Ethnic Disparities. *JAMA*. doi:10.1001/jama.2020.8598

Wong, P. (2019). Activists Demand Answers At Gowanus Rezoning Open House. *Bklyner*.

Wu, X., Nethery, R. C., Sabath, B. M., Braun, D., & Dominici, F. (2020). Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study. *medRxiv*, 2020.2004.2005.20054502. doi:10.1101/2020.04.05.20054502

Yan, Y., Yang, Y., Wang, F., Ren, H., Zhang, S., Shi, X., . . . Dong, K. (2020). Clinical characteristics and outcomes of patients with severe covid-19 with diabetes. *BMJ Open Diabetes Research & Care, 8*(1), e001343. doi:10.1136/bmjdrc-2020-001343

Yancy, C. W. (2020). COVID-19 and African Americans. *JAMA, 323*(19), 1891-1892. doi:10.1001/jama.2020.6548