

Respiratory Function and Racial Health Disparities With Residential Proximity to Coal Power Plants in Wisconsin

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ABSTRACT

Background: Burning fossil fuels, including coal, is the primary source of greenhouse gas emissions driving anthropogenic climate change and its associated health harms. Coal-fired power plants supply 23% of electricity nationally and 42% for Wisconsin, contributing to air pollution and associated respiratory diseases, cancers, and cardiovascular and neurologic disorders, especially for vulnerable populations. Authors seek to quantify residential distance from coal-fired power plants, pulmonary function of Wisconsin residents, and demographics.

Methods: Data from 2,327 adults aged 21-74 years was obtained from the Survey of the Health of Wisconsin database from 2008 through 2013. Pulmonary function was measured by expiratory volume in 1 second (FEV1) and forced vital capacity (FVC) as a ratio of FEV1/FVC. An average of at least 3 FEV1/FVC readings less than 80% was considered abnormal.

Results: Adults living near 1 of 11 coal-fired power plants may have worse pulmonary function. The odds ratio of FEV1/FVC values below 80% for those living within 35 km of a coal-fired power plant was 1.24 (95% CI, 0.90-1.70) when compared to those living greater than 35 km from a plant. While Black individuals made up 4.8% of the total sample population, they accounted for 13.3% of individuals living within 35 km of coal-fired power plants. Similarly, Hispanic populations accounted for 4.8% of those living within 35 km of a plant, while making up 2.8% of the sample population.

Interpretation: Significant disparities were found in residential proximity to Wisconsin coal-fired power plants for Black and Hispanic populations, with trends that support worse pulmonary function when living within 35 km of these plants. When linked with socioeconomic and racial/ethnic factors, closing down coal-fired power plants becomes a necessity to reduce disparities and address environmental injustices.

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BACKGROUND

Rising levels of greenhouse gas emissions are responsible for anthropogenic climate change and adversely affecting human health.^{1,2} The primary source of greenhouse gas emissions worldwide is burning fossil fuels—natural gas, petroleum fuels, and coal.^{3,4} Worldwide, nearly 1 in 5 people die prematurely secondary to air pollution from fossil fuel combustion.⁵ Coal use is a serious concern due to the large proportion of carbon dioxide emissions produced compared to other energy sources available. In 2019 in the United States, coal accounted for 23% of electricity generation and an astounding 60% of carbon dioxide (CO₂) emissions by the electric power sector.⁶ Certain states choose to use more coal than other states. In 2019, Wisconsin received 42% of its energy from coal, almost double the national percentage.⁷

There are myriad health harms associated with coal mining and the industrial processes necessary to generate electricity from coal.⁸⁻¹⁰ For decades, pulmonary diseases in underground workers (“black lung disease”) were reported, which drove policy initiatives to offer some protection to miners and workers at coal-fired power plants (CFPP)¹¹—the location where coal is burned and electricity generated. Air pollution from CFPP is the dominant health harm; robust scientific evidence documents clear adverse effects from particulate matter and toxic metals associated with respiratory disease, cardiac disease, cancer, neurologic development in children, low birth weight and preterm births, and mortality.^{8,10,12} In 2013 in Europe,

Table. Operational Power Plants in Wisconsin, 2008-2013

Coal-Fired Power Plant	Address	Geocoded Address	Closure Data
Columbia Energy Center (Alliant Energy Power Plant)	W8375 Murray Rd, Pardeeville, WI 53954	43.486111, -89.420278	To close by 2025
Edgewater Generating Station (Sheboygan Power Plant)	3739 Lakeshore Dr Sheboygan, WI	43.715556, -87.706389	To close by 2022
Elm Road Generating Station	11060 S Chicago Rd, Oak Creek, WI 53154	42.850058, -87.833035	None
Genoa Generating Station	s4651 WI-35, Genoa, WI 54632	43.559167, -91.231944	To close in 2021
John P. Madgett Generating Station	833Q+72 Alma, WI 54610	44.303056, -91.9125	None
Pleasant Prairie Power Plant	8000 95th St, Pleasant Prairie, WI 53158	42.538056, -87.904722	Closed in 2018
J. P. Pulliam Generating Station	1530 Bylsby Ave, Green Bay, WI 54303	44.54, -88.008611	Closed in 2018
Oak Creek Power Plant	11060 S Chicago Rd, Oak Creek, WI 53154	42.844444, -87.828611	To close by 2024
Weston Generating Station	2499 Old Hwy 51, Kronenwetter, WI 54455	44.858611, -89.649722	None
E. J. Stoneman Generating Station	716 Jack Oak Rd, Cassville, WI 53806	42.708333, -90.984722	Closed in 2015
Nelson Dewey Generating Station	11999 Co Hwy VV, Cassville, WI 53806	42.7225, -91.008611	Closed in 2015

emissions from coal caused 22,900 premature deaths—a number similar to road traffic deaths that year.¹³

The treatment of these health conditions result in increased emergency department visits¹⁴ and hospitalizations.¹⁵ Lost work-days¹⁶ and costly medication requirements—such as inhalers—associated with these conditions contribute to unnecessary health care costs and economic impact for patients affected.⁸ Modeling of closure of CFPP in Texas demonstrated greater economic health costs than the value of electricity generation.¹⁷ Moreover, the health effects were reversible in Pennsylvania when air quality improved following closures of 3 plants.¹⁸ Models for the US suggest early retirement of CFPP could save thousands of lives from reduced particulates alone.¹⁹

While all people are at risk of health harms from CFPP, specific groups are at increased risk of poor health. Exposure to air pollution from electricity generation was greatest for Black and lower-income individuals, with racial and ethnic disparities dominating.²⁰ Historically, these facilities were built adjacent to communities of color.^{21,22} To our knowledge, no studies have been conducted in Wisconsin to specifically examine the health impacts of CFPP on surrounding communities and the individual demographics of those exposed. As such, the authors seek to quantify the relationship between residential distance from CFPP and pulmonary function of Wisconsin residents, as well as reported race and ethnicity of these residents. We also examine policy changes that could have significant impacts in addressing racial disparities and health equity within Wisconsin.

METHODS

Survey of the Health of Wisconsin

Data was obtained from the Survey of the Health of Wisconsin (SHOW) database, which was collected from 2008 through 2013. The SHOW survey is modeled after the National Health and Nutrition Examination Survey (NHANES) and is directed at including information from a representative sample of Wisconsin residents. The SHOW database gathers information from surveys, physical exams, and biospecimens.

Study Participants

Participants were noninstitutionalized and nonactive duty, adult civilians (21-74 years old) from randomly selected households. Individuals were included in the study if they had valid spirometry data, as well as valid responses to control variable/demographic data. Random selection included a 2-stage probability-based cluster sampling approach, stratified by region and poverty level. Since the start of the program in 2008, sample sizes increased from 400 to more than 1,000 participants per year.

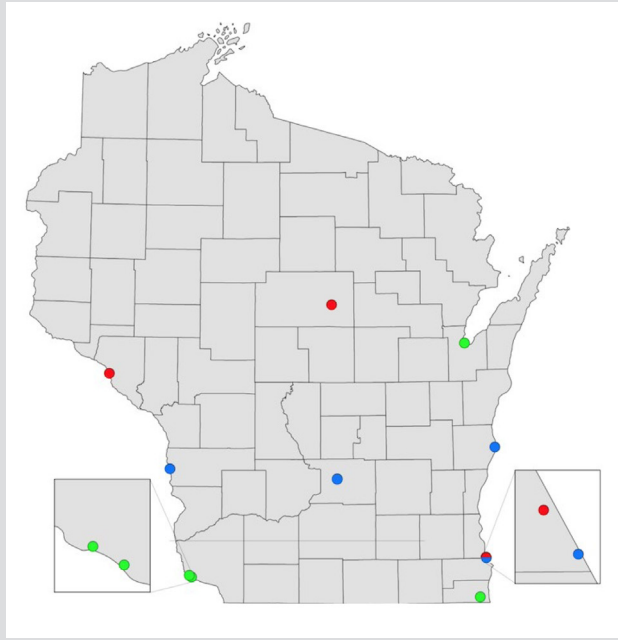
Control Variables

Individual socioeconomic status was controlled for by including measures of education level (less than high school, high school degree/GED [general education development], some post-secondary/college/associates degree, bachelor's degree, above bachelor's or professional degree), sex (female, male), race/ethnicity (non-Hispanic White, non-Hispanic Black/African American, Hispanic, other), age (21-34, 35-44, 45-54, 55-64, 65-74), insurance (uninsured, private, government, other independent insurance, multiple insurance types), occupation (working at a job or business, with a job or business but not at work—vacation or sick leave, not working but looking for work, not working at a job or business and not looking for work), asthma (currently have asthma), and total years smoking tobacco (<5 including never smoked, 5-10, 10-25, 25+) via multiple linear regression analyses.

Pulmonary Function

Pulmonary function was measured in all participants using forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC) as a ratio of FEV1/FVC. Measurements were taken up to 8 times, and an observation was considered valid only if 2 readings were within 10% of the maximum reading. An average of at least 3 FEV1/FVC readings was taken for each participant, and an average value less than 80% was considered abnormal. Despite an FEV1/FVC ratio of less than 70% widely considered to be diagnostic of chronic obstructive pulmonary

Figure 1. Location of 11 Coal-Fired Power Plants in Wisconsin



Red dots represent operational plants; green dots represent plants that have closed since 2013; blue dots represent plants with plans to close by 2025.

disease,^{23,24} we chose the cutoff of less than 80% to be an abnormal FEV1/FVC ratio, similar to others.²⁵

CFPP Distances

Location of CFPPs in Wisconsin that were operational for the entire duration of the study period were mapped; network distances were calculated using the point location of CFPP and the block group centroid corresponding to an individual's residential address. All participant records were geocoded to address and census block group level to allow for analysis of SHOW data. As in similar studies, we chose a distance that demonstrated the greatest discrimination in unadjusted analyses, which was found at 35 km.²⁶

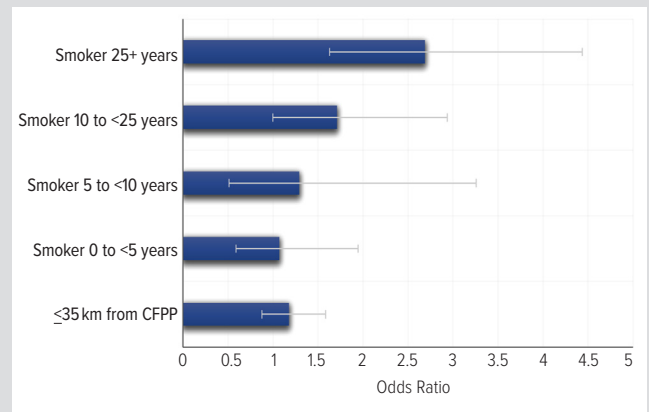
Statistical Analysis

Statistical analyses were completed using Stata 16.0. Survey regression models were used to assess associations between pulmonary function and distance to CFPPs alongside control variables to further assess protective and risk factors that may be contributing to abnormal pulmonary pathology. The geodetic distances (ie, measurements along the earth's surface) between CFPP locations and participant residence were calculated using ArcGIS software.²⁶ Project approval was granted through the Medical College of Wisconsin Institutional Review Board.

RESULTS

Eleven coal-fired power plants were operating in Wisconsin from 2008 through 2013 as shown in the Table and mapped on Figure 1. The majority of CFPPs were in the central and southern parts

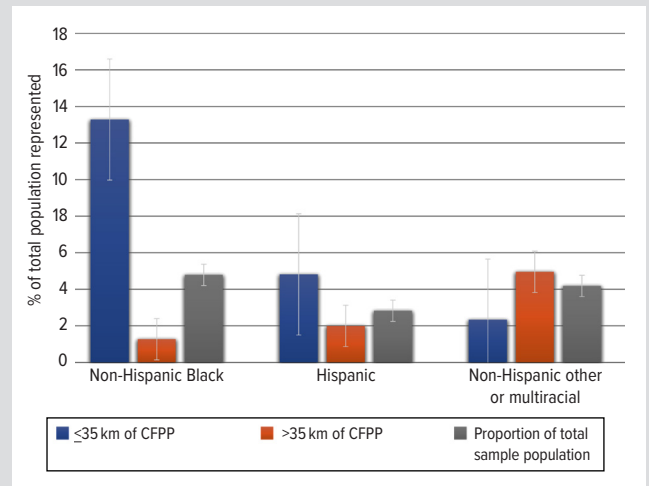
Figure 2. Respiratory Function of Residential Proximity of Coal-Fired Power Plant Compared with Impact of Years of Tobacco Use



Odds ratio (with 95% CI) of demographic factors and distance from coal-fired power plant (CFPP) and tobacco use as a smoker in years showed in relation to respiratory function as measured by FEV1/FVC ratio.

Abbreviations: CFPP, coal-fired power plant; FEV1, forced expiratory volume in 1 second; FVC, forced vital capacity.

Figure 3. Reported Race/Ethnicity and Proximity to Coal-Fired Power Plant



Abbreviation: CFPP, coal-fired power plant.

of the state. The highest concentration of plants, including those that have closed since 2013, were in the southeastern corner situated along Lake Michigan and the city of Milwaukee—the largest city in the state by population.

A total of 2,327 adults (21-74 years old) were included in the present study. Of participants, 44.6% were male. Spirometry values as measured by FEV1/FVC were lower for those living within 35 km from one of the 11 CFPP (OR 1.24; 95% CI, 0.90-1.70) compared to those living further than 35 km from a CFPP. Figure 2 further details this relationship in comparison to the respiratory health of individuals with differing levels of smoking history using an odds ratio in relation to closer distance to a CFPP. Results support that exposure to CFPP trended towards similar effects seen in smoking tobacco for several years.

Figure 3 shows reported race/ethnicity of survey respondents and proximity to a CFPP. While Black individuals made up 4.8% (n=112) of the total sample population, they accounted for 13.3% (n=91) of the individuals living within 35 km of a CFPP. Similarly, those who identified as Hispanic accounted for 4.8% (n=33) of those living within 35 km of a CFPP, while only making up 2.8% (n=66) of the sample population. Non-Hispanic White individuals composed the greatest proportion of respondents at 88%.

DISCUSSION

This is the first study in Wisconsin to assess pulmonary function and disparities in relation to residential distance from coal-fired power plants. Results suggest worse pulmonary function as measured by spirometry values in those residing closer to CFPPs, with statistically significant higher percentages of Black and Hispanic survey respondents living near CFPPs.

Our findings suggest a nonsignificant trend towards greater likelihood of worse pulmonary function (FEV1/FVC \leq 0.8) in adult respondents living within 35 km of a CFPP, compared to those residing further away. As seen in Figure 2, this association with decreased FEV1/FVC ratio may be similar to trends seen in smokers, a demographic that is strongly associated with increased risk of obstructive pulmonary disease.²⁷ Although the confidence interval in our study crossed 1, these results were likely influenced by the small sample size of available survey data, as well as this being a statewide rather than national study. A larger sample size may support a significant association. A previous study found a stronger association and demonstrated significantly worse spirometry measurements for villagers living within 5 km of CFPPs compared to those living further than 30 km away.²⁸ The close proximity may have strengthened their findings.

Based on the study, we recommend policies to limit exposure to residents living near CFPPs until complete plant closures occur, since closures are frequently announced years in advance. A report demonstrated that more than 1.2 million people live within 20 km of CFPPs in Wisconsin.²⁹ Ensuring these individuals are protected from undue health harms represents a significant opportunity to reduce health burdens right now. Specific measures could address vulnerable populations and work to increase adaptive capacity with a focus on health. Cooperation with housing authorities, policymakers, health professionals, local and state public health officials, and urban planners is needed to reduce these effects—especially when combined with frequently compounded climate-related health threats of extreme heat exposure and allergens.

We found that areas nearest CFPP had a higher percentage of survey respondents who identified as Black or Hispanic compared with White. Tessum and colleagues found Black individuals are exposed 18% more to particulate matter from coal electric generation while Hispanic individuals were exposed less at -38%.³⁰

Another study demonstrated racial disparities for people living near polluting industrial facilities, particularly in the Midwest.³¹ Our results showed statistically significant discrepancies in race/ethnicity for those living near CFPPs, although lower than some US communities have reported.²² In the United States, nearly 6 million people live within 5 km of CFPPs and 39% are people of color.²² This study adds yet another example of pervasive racial and ethnic disparities in the United States—such as that of redlining leading to outcomes of reduced access to greenspace³² or increased exposure to extreme heat.³³ Since the time of the study, 4 CFPPs have closed and 4 more plan to close in coming years. The most recent projected closure of the Columbia Power Plant by 2025 was announced in February 2021. The initiatives align with Wisconsin's goal to be carbon neutral by 2050.

While closing the 3 remaining Wisconsin CFPPs may seem to be a large transition, Alberta—a Canadian province similar to Wisconsin in both population and gross domestic product—committed to phase-out of coal power and thermal coal mines by 2030.³⁴ The province, which has the third largest oil reserve in the world behind Saudi Arabia and Venezuela, is also aiming to have 30% of its power sourced from renewables by 2030. This transition was driven primarily by the low global coal prices and logistical difficulties of transporting coal outside of the province, climate change impacts including melting glaciers within the province, and health care impacts from air pollution estimated at \$3 billion in negative health outcomes.³⁴

Similarly, there are significant economic and health gains for Wisconsin in transitioning to clean energy.³⁵ In-state production of 100% clean energy would reduce air pollution and thereby save \$1 billion every year in avoided health damages; it would create 152,000 net new jobs and grow Wisconsin's gross domestic product by 5%.³⁵ Such actions support a Wisconsin Medical Society resolution to support policies that limit warming to 1.5 °C and reduce emissions.³⁶ Nationally, 2 of 6 key recommendations from the Lancet US Policy Brief are to remove US fossil fuel subsidies and shift to zero-carbon electricity by 2035.³⁷ Shutting down CFPPs in a just and equitable manner is a key component to reach these goals. It also challenges industries such as health care systems, academia, and organizations to assess their own electricity sources and funding ties with fossil fuel companies. These are practicable actions that actively work to reduce inequities and injustices across our urban and rural communities.

International leaders and policymakers have an opportunity to transform the landscape of global CFPPs and energy for health. Greenhouse gas emissions continue to drive anthropogenic climate change and resulting rising average global temperatures and supercharged extreme weather events that leave lasting impact.² While the main producers of these emissions tend to be the larger and richer economies, it is the poorest populations that frequently suffer the most.³⁸ Shutting down CFPPs and investing in clean energy becomes not only a moral request but a necessity for health

as we build back across sectors following a global pandemic. As further incentive, there has been a 5-factor reduction in renewable costs since 2010,³⁸ and the cost of producing new energy via renewables such as wind or solar is now cheaper than coal in many countries, including the United States.³⁹ Further research investments may help guide specific actions and return on investments that reduce fossil fuel pollution and improve health.

Strengths and Limitations

The study has several strengths. With a small sample size, an effect was found; and even with breaking down the sample more by race and ethnicity, an effect was still evident. Survey respondents were chosen randomly, which reduces bias. We also chose 6 years of data to attempt to minimize variation in sample and population and controlled for multiple variables.

A few limitations remain. While the FEV1/FVC measurement is a valuable tool, it does not provide the complete clinical picture of the respiratory harms of CFPP and does not address the frequently coexisting complexities of duration or intensity of exposure. The survey was also 2,327 individuals randomly sampled in the state and only complete survey data were included, which may be a potential source of bias. The survey did not include children. We believe this may underestimate the true effect due to increased duration of exposure and risk of children. Finally, distance was not stratified. As such, further research could expand upon specific areas of greatest distance linked to maximum health harms and benefits.

CONCLUSIONS

This paper demonstrates significant racial and ethnic disparities in those living near CFPPs and trends in reduced pulmonary function for those living closer to the plants. As we work to rapidly reduce racial disparities in the United States, our work suggests yet another avenue to address environmental exposures and pollution from fossil fuels. Policies should be created to improve air quality and health of Wisconsin residents, especially those at greatest risk of poor health. The structures that communities and community leaders have created can strengthen people through new policies that prioritize health and justice for all.

Funding/Support: None declared.

Financial Disclosures: None declared.

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