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

Michael Hii, BS; Kirsten Beyer, PhD, MPH, MS; Sima Namin, PhD; Kristen Malecki, PhD, MPH; Caitlin Rublee, MD, MPH

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 were 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.

Conclusions: 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.

• • •

Author Affiliations: School of Medicine, Medical College of Wisconsin (MCW), Milwaukee, Wisconsin (Hii); Division of Epidemiology, Institute for Health and Equity, MCW, Milwaukee, Wisconsin (Beyer, Namin); Department of Population Health Sciences, University of Wisconsin-Madison, Madison, Wisconsin (Malecki); Department of Emergency Medicine, MCW, Milwaukee, Wisconsin (Rublee); Institute for Health and Equity, MCW, Milwaukee, Wisconsin (Rublee).

Corresponding Author: Caitlin Rublee, MD, MPH, Medical College of Wisconsin, 8701 W Watertown Plank Rd, Wauwatosa, WI 53226; email crublee@mcw.edu.

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 (CO_2) 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, 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 visits[14] and hospitalizations.[15] Lost work days[16] 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/associate's 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 to <10, 10 to <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 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.

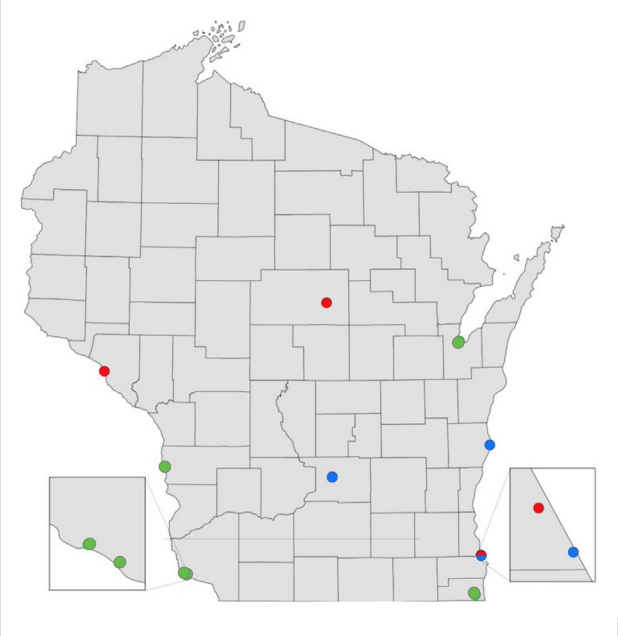
RESULTS

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

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	Closed 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

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.

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 CFPPs (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≤0.8) in adult respondents living within 35 km of a CFPP, compared to those residing farther 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 farther 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.

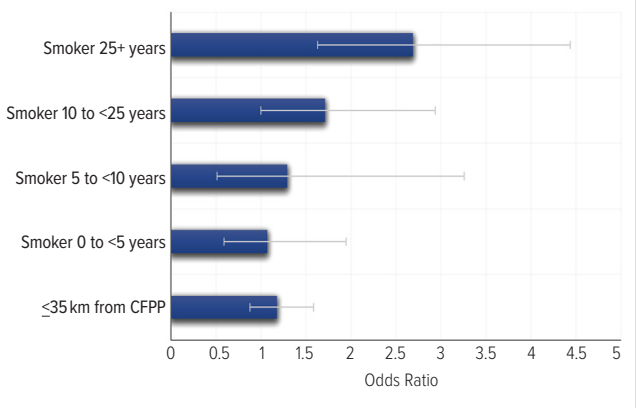
We found that areas nearest CFPPs had a higher percentage of survey respondents who identified as Black or Hispanic compared with White. Tessum and colleagues found Black individuals are exposed 18% more to particulate matter from coal electric generation, while Hispanic individuals were exposed less 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 greenspace[32] or increased exposure to extreme heat.[33] Since the time of the study, 5 CFPPs have closed and 3 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 phaseout 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.

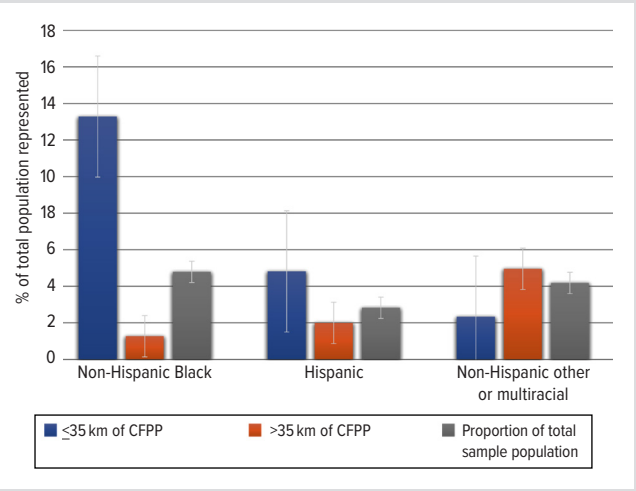
International leaders and policymakers have an opportunity to transform the landscape of global CFPPs and energy for health. Greenhouse gas emissions continue to drive anthropogenic climate change and resulting rising average global temperatures and supercharged extreme weather events that leave lasting 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

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.

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 sample 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 sample 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.

REFERENCES

1. Crimmins A, Balbus J, Gamble J, et al. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. US Global Change Research Program; 2016.

2. Intergovernmental Panel on Climate Change. *Climate Change 2014: Synthesis Report.* Intergovernmental Panel on Climate Change; 2014. Accessed May 31, 2021. https://www.ipcc.ch/report/ar5/syr/

3. Global emissions. Center for Climate and Energy Solutions. Accessed January 21, 2021. https://www.c2es.org/content/international-emissions/

4. Energy and the environment explained: where greenhouse gases come from. US Energy Information Administration. Updated August 11, 2020. Accessed January 22, 2020. https://www.eia.gov/energyexplained/energy-and-the-environment/where-greenhouse-gases-come-from.php

5. Vohra K, Vodonos A, Schwartz J, Marais EA, Sulprizio MP, Mickley LJ. Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: results from GEOS-Chem. *Environ Res*. 2021;195:110754. doi:10.1016/j.envres.2021.110754

6. Electricity explained. US Energy Information Administration. Updated March 20, 2020. Accessed January 21, 2021. https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php

7. Wisconsin state profile and energy estimates. US Energy Information Administration Updated May 21, 2020. Accessed May 17, 2021. https://www.eia.gov/state/index.php?sid=WI

8. Burt E, Orris P, Buchanan S. *Scientific Evidence of Health Effects from Coal Use in Energy Generation.* University of Illinois at Chicago School of Public Health; 2013. Accessed May 17, 2021. https://noharm-uscanada.org/documents/scientific-evidence-health-effects-coal-use-energy-generation

9. Epstein PR, Buonocore JJ, Eckerle K, et al. Full cost accounting for the life cycle of coal. *Ann N Y Acad Sci.* 2011;1219:73-98. doi:10.1111/j.1749-6632.2010.05890.x

10. Hendryx M, Zullig KJ, Luo J. Impacts of coal use on health. Annu Rev Public Health. 2020;41:397-415. doi:10.1146/annurev-publhealth-040119-094104

11. Bridbord K, Costello J, Gamble J, et al. Occupational safety and health implications of increased coal utilization. *Environ Health Perspect.* 1979;33:285-302. doi:10.1289/ehp.7933285

12. Kravchenko J, Lyerly HK. The impact of coal-powered electrical plants and coal ash impoundments on the health of residential communities. *N C Med J.* 2018;79(5):289-300. doi:10.18043/ncm.79.5.289

13. *Europe's Dark Cloud: How Coal-Burning Countries Are Making Their Neighbours Sick.* CAN Europe; HEAL; WWF European Policy Office; Sandbag; 2016. Accessed July 12, 2021. https://env-health.org/IMG/pdf/dark_cloud-full_report_final.pdf

14. Rodríguez E, Ferrer J, Martí S, Zock JP, Plana E, Morell F. Impact of occupational exposure on severity of COPD. *Chest*. 2008;134(6):1237-1243. doi:10.1378/chest.08-0622

15. Slama A, Śliwczyński A, Woźnica J, et al. Impact of air pollution on hospital admissions with a focus on respiratory diseases: a time-series multi-city analysis. *Environ Sci Pollut Res Int.* 2019;26(17):16998-17009. doi:10.1007/s11356-019-04781-3

16. Logue JM, Price PN, Sherman MH, Singer BC. A method to estimate the chronic health impact of air pollutants in U.S. residences. *Environ Health Perspect.* 2012;120(2):216-222. doi:10.1289/ehp.1104035

17. Strasert B, Teh SC, Cohan DS. Air quality and health benefits from potential coal power plant closures in Texas. *J Air Waste Manag Assoc.* 2019;69(3):333-350. doi:10.1080/10962247.2018.1537984

18. Russell MC, Belle JH, Liu Y. The impact of three recent coal-fired power plant closings on Pittsburgh air quality: a natural experiment. *J Air Waste Manag Assoc.* 2017;67(1):3-16. doi:10.1080/10962247.2016.1170738

19. Energy Policy Solutions. Energy Policy Simulator. Energy Innovation Policy & Technology LLC. Accessed January 22, 2021. https://us.energypolicy.solutions/scenarios/home

20. Thind MPS, Tessum CW, Azevedo IL, Marshall JD. Fine particulate air pollution from electricity generation in the US: health impacts by race, income, and geography. *Environ Sci Technol.* 2019;53(23):14010-14019. doi:10.1021/acs.est.9b02527

21. Ash M, Boyce JK. Racial disparities in pollution exposure and employment at US industrial facilities. *Proc Natl Acad Sci U S A*. 2018;115(42):10636-10641. doi:10.1073/pnas.1721640115

22. Wilson A, Patterson J, Wasserman K, et al. *Coal Blooded: Putting Profits Before People.* National Association for the Advancement of Colored People; Indigenous Environmental Network; Little Village Environmental Justice Organization; 2016. Accessed May 31, 2021. https://naacp.org/resources/coal-blooded-putting-profits-people

23. Pellegrino R, Viegi G, Brusasco V, et al. Interpretative strategies for lung function tests. *Eur Respir J.* 2005;26(5):948-968. doi:10.1183/09031936.05.00035205

24. Rabe KF, Hurd S, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. *Am J Respir Crit Care Med.* 2007;176(6):532-555. doi:10.1164/rccm.200703-456SO

continued on page 105

Acknowledgements: The authors are grateful for the collaboration and support of all the residents and staff at the Milwaukee Women's Center, with a special thank you to the shelter manager Penelope Dixon. We also thank the staff and the leadership of the Department of Family and Community Medicine at MCW for their unwavering support.

Financial Disclosures: None declared.

Funding/Support: This research was supported in part by the Medical College of Wisconsin's Community of Innovators Award.

Appendix: Available online at wmjonline.org.

REFERENCES

1. Matoba N, Collins JW Jr. Racial disparity in infant mortality. *Semin Perinatol.* 2017;41(6):354-359. doi:10.1053/j.semperi.2017.07.003

2. MacDorman MF, Matthews TJ, Mohangoo AD, Zeitlin J. International comparisons of infant mortality and related factors: United States and Europe, 2010. *Natl Vital Stat Rep.* 2014;63(5):1-6.

3. Infant mortality. Centers for Disease Control and Prevention. Published September 10, 2020. Accessed April 12, 2021. https://www.cdc.gov/reproductivehealth/maternalinfanthealth/infantmortality.htm

4. Ngui E, Michalski K, LeCounte E, Mohr A. *2017 City of Milwaukee Fetal Infant Mortality Review Report*. Milwaukee Health Department; Joseph J Zilber School of Public Health; 2017. Accessed August 1, 2021. https://city.milwaukee.gov/ImageLibrary/Groups/healthAuthors/ADMIN/PDFs/PressReleases/2017/FIMRReport2017FINAL.pdf

5. WISH – infant mortality module. Wisconsin Department of Health Services. Accessed April 21, 2021 and December 3, 2021. https://www.dhs.wisconsin.gov/wish/infant-mortality/index.htm

6. Beal AC, Redlener I. Enhancing perinatal outcome in homeless women: the challenge of providing comprehensive health care. *Semin Perinatol.* 1995;19(4):307-313. doi:10.1016/s0146-0005(05)80046-1

7. Bassuk EL, Weinreb L. Homeless pregnant women: two generations at risk. *Am J Orthopsychiatry*. 1993;63(3):348-357. doi:10.1037/h0085034

8. St Martin BS, Spiegel AM, Sie L, et al. Homelessness in pregnancy: perinatal outcomes. *J Perinatol*. 2021;41(12):2742-2748. doi:10.1038/s41372-021-01187-3

9. Talih M, Huang DT. *Measuring Progress Toward Target Attainment and the Elimination of Health Disparities in Healthy People 2020.* National Center for Health Statistics; 2016. Healthy People Statistical Notes 27. Accessed August 1, 2021. https://www.cdc.gov/nchs/data/statnt/statnt27.pdf

10. McCormick MC, Litt JS, Smith VC, Zupancic JA. Prematurity: an overview and public health implications. *Annu Rev Public Health*. 2011;32:367-379. doi:10.1146/annurev-publhealth-090810-182459

11. Smith A. *Who is Homeless in Wisconsin?* A Look at Statewide Data. Wisconsin Family Impact Seminars; 2017. Accessed August 1, 2021. https://wisfamilyimpact.org/wp-content/uploads/2017/01/FIS35-Adam-Smith.pdf

12. Ake T, Diehr S, Ruffalo L, et al. Needs assessment for creating a patient-centered, community-engaged health program for homeless pregnant women. *J Patient Cent Res Rev.* 2018;5(1):36-44. doi:10.17294/2330-0698.1591

13. Meurer LN, Young SA, Meurer JR, et al. The urban and community health pathway: preparing socially responsive physicians through community-engaged learning. *Am J Prev Med.* 2011;41(4 Suppl 3):S228-S236. doi:10.1016/j.amepre.2011.06.005

14. Strauss AL, Corbin JM. B*asics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory.* 2nd ed. Sage; 1998.

15. Miles MB, Huberman AM. *Qualitative Data Analysis: An Expanded Sourcebook*. Sage Publications; 1994.

16. Merriam SB. Adult learning theory for the twenty-first century. *New Dir Adult Contin Educ*. 2008;2008(119):93-98. doi:10.1002/ace.309

17. Freire P. *Pedagogy of the Oppressed*. Continuum; 1970.

18. Cardwell MS. Stress: pregnancy considerations. *Obstet Gynecol Surv.* 2013;68(2):119-129. doi:10.1097/OGX.0b013e31827f2481

19. *Wisconsin PRAMS 2016-2017 Surveillance Report.* Wisconsin Department of Health Services; 2019. P-02500. Accessed August 1, 2021. https://www.dhs.wisconsin.gov/publications/p02500.pdf

20. Sinha B, Chowdhury R, Sankar MJ, et al. Interventions to improve breastfeeding outcomes: a systematic review and meta-analysis. *Acta Paediatr.* 2015;104(467):114-134. doi:10.1111/apa.13127

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

REFERENCES *continued from page 98*

25. Yu S, Park S, Park CS, Kim S. Association between the ratio of FEV_1 to FVC and the exposure level to air pollution in neversmoking adult refractory asthmatics using data clustered by patient in the Soonchunhyang asthma cohort database. *Int J Environ Res Public Health.* 2018;15(11):2349. doi:10.3390/ijerph15112349

26. *ArcGIS.* Release 10.5. Environmental Systems Research Institute; 2016.

27. Wheaton AG, Liu Y, Croft JB, et al. Chronic obstructive pulmonary disease and smoking status - United States, 2017. *MMWR Morb Mortal Wkly Rep*. 2019;68(24):533-538. doi:10.15585/mmwr.mm6824a1

28. Karavuş M, Aker A, Cebeci D, Taşdemir M, Bayram N, Cali S. Respiratory complaints and spirometric parameters of the villagers living around the Seyitomer coal-fired thermal power plant in Kütahya, Turkey. *Ecotoxicol Environ Saf.* 2002;52(3):214-220. doi:10.1006/eesa.2002.2158

29. Sierra Club. The Cost of Coal. Sierra Club; 2020. Accessed May 31, 2021. https://www.sierraclub.org/sites/www.sierraclub.org/files/sce-authors/u2196/SierraClub_CostOfCoal.pdf

30. Tessum CW, Paolella DA, Chambliss SE, Apte JS, Hill JD, Marshall JD. PM2.5 polluters disproportionately and systemically affect people of color in the United States. *Sci Adv.* 2021;7(18):eabf4491. doi:10.1126/sciadv.abf4491

31. Mohai P, Lantz PM, Morenoff J, House JS, Mero RP. Racial and socioeconomic disparities in residential proximity to polluting industrial facilities: evidence from the Americans' Changing Lives Study. *Am J Public Health.* 2009;99 Suppl 3(Suppl 3):S649-S656. doi:10.2105/AJPH.2007.131383

32. Nardone A, Rudolph KE, Morello-Frosch R, Casey JA. Redlines and greenspace: the relationship between historical redlining and 2010 greenspace across the United States. *Environ Health Perspect.* 2021;129(1):17006. doi:10.1289/EHP7495

33. Hoffman JS, Shandas V, Pendleton N. The effects of historical housing policies on resident exposure to intra-urban heat: a study of 108 US urban areas. *Climate*. 2020;8(1). doi:10.3390/cli8010012

34. IISD. *The Power of Together: Annual Report for 2018-2019.* International Institute for Sustainable Development; 2019. Accessed July 12, 2021. https://www.iisd.org/publications/annual-report/iisd-annual-report-2018-2019

35. Patz JA, Lois AN, Clifford S, Brossard D, Maibach E. *Medical Alert! Climate Change is Harming our Health in Wisconsin*. University of Wisconsin-Madison; 2020. Accessed May 31, 2021.https://ghi.wisc.edu/health-climate-cities/

36. Wisconsin Medical Society. Wisconsin Medical Society: Climate Change Position Resolution. The Medical Society Consortium. Posted August 28, 2020. Accessed January 18, 2021. https://medsocietiesforclimatehealth.org/medical-society-policy-statements/wisconsin-medical-society-climate-change-position-resolution/

37. Salas RN, Lester PK, Hess JJ. *The Lancet Countdown on Health and Climate Change: Policy Brief for the United States of America.* Lancet Countdown; 2020. Accessed July 12, 2021. https://www.lancetcountdownus.org/2020-lancet-countdown-u-s-brief/

38. IRENA. *Renewable Power Generation Costs in 2019*. International Renewable Energy Agency; 2020. Accessed December 29, 2020. https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

39. Carbon Tracker. *How to Waste Over Half a Trillion Dollars: The Economic Implications of Deflationary Renewable Energy for Coal Power Investments.* Carbon Tracker; 2020. Accessed December 29, 2020. https://carbontracker.org/reports/how-to-waste-over-half-a-trillion-dollars/

advancing the art & science of medicine in the midwest

WMJ

WMJ (ISSN 1098-1861) is published through a collaboration between The Medical College of Wisconsin and The University of Wisconsin School of Medicine and Public Health. The mission of *WMJ* is to provide an opportunity to publish original research, case reports, review articles, and essays about current medical and public health issues.

Visit www.wmjonline.org to learn more.