An Analysis of COVID-19, Air Quality, Race and Socioeconomic Status in Georgia

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Written By: Olivia E. Chatman
Supervised by: Dr. Brian Stone, Jr.

GEORGIA INSTITUTE OF TECHNOLOGY, SCHOOL OF CITY & REGIONAL PLANNING

INTRODUCTION

Presentation of Issue

As a requirement of the Clean Air Act established in 1970, the United States Environmental Protection agency sets forth National Ambient Air Quality Standards to oversee the release of Criteria Air Pollutants that pose a threat to public health and welfare. Included in these pollutants is $PM_{2.5}$, a microscopic fine particle that enters the atmosphere as a result of combustion processes and can cause adverse health effects including respiratory issues and lung disease. In the United States, the existence of environmental hazards, such as $PM_{2.5,}$ have disproportionately impacted communities of color and of lower socioeconomic statuses as they do not "receive the same degree of protection from environmental and health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn, and work"[1], an issue also known as environmental injustice.

Relevant to the respiratory health of the various populations in this country, in late 2019, the rapid spread of the novel COVID-19 respiratory virus resulted in a global pandemic and major shutdowns around the world, causing over 500,000 deaths by

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[1] United States Environmental Protection Agency. 2020. "Environmental Justice." Accessed October 2020. https://www.epa.gov/environmentaljustice

April of 2021 in the United States alone[2]. With no existing human immunity to the virus and the fact that it is more contagious than other viruses of the same family, COVID-19 has had major impacts on the day to day functioning of society and has resultingly lead to a call for a reconsideration of public health in regard to safety and preventive measures that can be implemented on both an individual and community-wide scale. In addition to situational factors that determine the likelihood of contracting COVID-19, such as duration of exposure and distance from infected person, "race and ethnicity are risk markers for other underlying conditions that impact health — including socioeconomic status, access to health care, and increased exposure to the virus due to occupation (e.g., frontline, essential, and critical infrastructure workers)," [3] which is reflected in the higher existence of COVID-19 cases, hospitalizations, and deaths among non-white Americans (Figure 1). Environmental factors, both built and natural, also contribute to overall health outcomes, tying the COVID-19 pandemic back to the questions around the geospatial distributions of air toxins in this country. In the face of an unprecedented respiratory virus and already existing inequitable environmental conditions, identifying the correlations between the air quality and COVID-19 occurrences among BIPOC groups, also known as Black, Indigenous, and People of

[2] National Center for Health Statistics. 2020. "Daily Updates of Totals by Week and State." *Centers for Disease Control and Prevention*. Accessed April 2021. https://www.cdc.gov/nchs/nvss/vsrr/covid19/index.htm.

[3] Centers for Disease Control and Prevention. 2020. "COVID-19 Hospitalization and Death by Race/Ethnicity." *Coronavirus Disease 2019 (COVID-19)*. Accessed October 2020. https://www.cdc.gov/coronavirus/2019-ncov/covid-data/investigations-discovery/hospitalization-death-by-race-ethnicity.html.

Color[4], is essential to moving forward in addressing the issue of environmental injustice and health disparities among disadvantaged and vulnerable groups.

Because air quality monitoring and management is implemented at the state level, the study area of this paper is the State of Georgia, which has seen a total of 851,306 cases and 16,533 deaths since the beginning of the COVID-19 pandemic[5]. This study will examine the question of whether Black people in Georgia are more likely to experience disproportionality higher levels of PM2.5 and COVID-19 infection rates than white communities, relative to their population percentages, through the conduction of literature review identifying current knowledge and research gaps related to COVID-19, air quality and environmental justice. A spatial analysis of the relationship between PM2.5 air pollution, COVID-19 cases and deaths, race demographics, as well as socioeconomic factors in Georgia counties will reveal any disparities related to health and air among Black populations. It is predicted that counties with average higher PM2.5 levels will contain higher populations of Black people, that increased concentrations of PM2.5 will be linked to higher case and death rates of COVID-19, which will disproportionately impact Black people, and that case counts and death rates of COVID-19 will not follow population percentages of race for

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[4] The BIPOC Project. 2020. "About Us." Accessed April 2021. https://www.thebipocproject.org/about-us.
[5] Georgia Department of Public Health. 2020. "Georgia Department of Public Health Daily Status Report." Accessed October 2020. https://dph.georgia.gov/covid-19-daily-status-report.

each county, but will be disproportionately higher for Black people. The analysis performed in this study may serve as a guide for future state-level research related to the topic, in addition to providing recommendations to key public health professionals, environmentalist, and public policy makers for addressing health disparities and environmental injustice in the state of Georgia.

LITERATURE REVIEW

A review of current literature will offer a better look into the historical and current knowledge and regulations around air quality monitoring and standards, the novel coronavirus pandemic, and health disparities reflected in the occurrences of the two. The subsequent section will explore current information to define and establish key factors related to the research topic.

PM2.5 Background

$PM_{2.5}$ is an Environmental Protection Agency designated criteria air pollutant that includes fine particulate matter that is 2.5 micrometers or smaller, in comparison to the larger, less harmful PM_{10}[6]. Other criteria air pollutants include Carbon Monoxide

[6] United States Environmental Protection Agency. 2020. "Particulate Matter (PM) Pollution." Accessed November 2020. Particulate Matter (PM) Pollution. https://www.epa.gov/pm-pollution.

(CO), Lead (Pb), Nitrogen Dioxide (NO_2), Ozone (O_3) and Sulfur Dioxide (SO_2), and PM_{10}. Typically, sources of particulate matter include combustion reactions in a range of activities including industrial processes, wildfires, motor vehicles use and power plant releases[7]. As the small size of $PM_{2.5}$ gives it the ability to penetrate the lung tissue and even enter the blood stream, exposure to the pollutant often results in damage to both the heart and lungs including problems such as "premature death…, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing"[6]. Extremely vulnerable populations to such air pollution include the elderly, children, and those with preexisting lung and heart conditions[8].

Under Sections 108 and 109 of the Clean Air Act, established in 1970 and amended in 1990, the EPA is required to set National Ambient Air Quality Standards (NAAQS) that regulate the above stated pollutants. These standards fall into two categories of primary and secondary: primary standards include requirements for protection of human health while secondary standards relate to protections of public welfare including animals, agriculture and the built environment. Today, the process of establishing NAAQS involves a lengthy assessment of existing science, risks,

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[7] Georgia Department of Natural Resources, Environmental Protection Division, Air Protection Branch. 2018. *2017 Ambient Air Surveillance Report.* Accessed November 2020. https://airgeorgia.org/docs/report17.pdf.

[8] Air Georgia. 2020. "Information about Particulate Matter (FINE) PM 2.5." *Ambient Air Monitoring Program.* Accessed November 2020. https://airgeorgia.org/docs/report17.pdf.

exposures, and policies related to the pollutant being analyzed[9], a process that happens at least every five years[10]. Once NAAQS are put in place, pollutants are managed at the state level with certain areas within states being designated as attainment areas if they meet the standards, and nonattainment areas if they exceed them[6].

Standards specifically implemented to address $PM_{2.5}$ have been previously established in 1997, 2006, and 2012[6]. In 1997, the annual standard was "65 μg/m^3 based on the 3-year average of the annual 98th percentile concentrations" and the daily standard was "15 μg/m^3, based on the 3-year average of annual mean $PM_{2.5}$ concentrations"[11]. In 2020, it was decided that the 2012 standards would be retained which includes primary and secondary annual averages of 12.0 μg/m^3 and 15.0 μg/m^3, respectively, and 24-hour standards with 98th percentile forms and levels of 35 μg/ m^3 [6].

Under the Clean Air Act, states are also required to create State Implementation Plan (SIPS) which outline "how and when an area will achieve attainment of a standard

[9] United States Environmental Protection Agency. 2020. "Process of Reviewing the National Ambient Air Quality Standards." Accessed November 2020. https://www.epa.gov/criteria-air-pollutants/process-reviewing-national-ambient-air-quality-standards.

[10] Flynn, Aaron; Lucinda M. Langworthy. 2018. "The New NAAQS Process Begins to Take Shape." *The Magazine for Environmental Managers*. Accessed November 2020. https://www.huntonak.com/images/content/5/5/v2/55447/NewNAAQSReviewProcessBeginstoTakeShape.pdf.

[11] United States Environmental Protection Agency. 2020. "What are the Air Quality Standards for PM." Accessed November 2020. https://www3.epa.gov/region1/airquality/pm-aq-standards.html.

or how an area that has achieved attainment will maintain attainment"[12]. Within a SIP are attainment demonstrations, maintenance plans, and redesignation requests for each region in the state. In 2005, four nonattainment regions were designated by the EPA in Georgia including Atlanta, Floyd, Macon, and Chattanooga (which contains regions of Tennessee and Alabama)[13]. In 2011, the EPA ruled that each region attained the 1997 $PM_{2.5}$ standards based on three years of monitoring, which allowed the Georgia Department of Natural Resources Air Protection Branch in 2012 to submit and be approved for a redesignation request and maintenance plan for each of the four portions that would be used to update their existing SIP[13]. While there are currently no nonattainment regions in Georgia[14], air quality and concentrations of PM2.5 vary around the state[7].

COVID-19 Background

COVID-19 is a respiratory illness caused by a coronavirus called SARS-CoV-2[15]. The primary mode of infection is through both visible and microscopic respiratory droplets

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[12] Georgia Department of Natural Resources, Environmental Protection Division, Air Protection Branch. 2020. "State Implementation Plan Revisions for Air Quality Standards." Accessed November 2020. https://epd.georgia.gov/air-protection-branch/air-branch-programs/planning-and-support-program/state-implementation-plan.

[13] Georgia Department of Natural Resources, Environmental Protection Division, Air Protection Branch. 2020. "PM2.5 SIPs." Accessed November 2020. https://epd.georgia.gov/pm25-sips.

[14] United States Environmental Protection Agency. 2020. "Georgia Nonattainment/Maintenance Status for Each County by Year for All Criteria Pollutants." *Green Book*. Accessed November 2020. https://www3.epa.gov/airquality/greenbook/anayo_ga.html.

[15] Centers for Disease Control and Prevention. 2020. "Scientific Brief: SARS-CoV-2 and Potential Airborne Transmission." *Coronavirus Disease 2019 (COVID-19)*. Accessed November 2020. https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html.

of an infected person that one may be exposed to through direct contact or airborne transmission[15]. Symptoms of infection appear two to fourteen days after initial exposure and present a range of possible bodily responses including fever, dry cough, shortness of breath, headache, and fatigue[16]. Spread of the virus is prevented through social distancing of six or more feet, the use of face masks in public settings, washing of hands, and disinfecting of shared spaces[17]. The top contributing causes of death resulting from viral infection include Influenza or Pneumonia, while other conditions such as circulatory diseases, sepsis, malignant neoplasms, diabetes, obesity, Alzheimer, dementia, and renal features are also less common contributing factors to death[18].

In addition to the presentation of symptoms during the period of contagious infection, many lingering symptoms have been reported in patients weeks after testing negative, including loss of taste or smell, confusion and headaches[19]. Moreover, a diagnosis of COVID-19 may increase the risk of other long-term health problems in patients including heart, lung, brain, musculoskeletal and nervous system damage, along with mental health disorders[19].

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[16] Centers for Disease Control and Prevention. 2020. "Symptoms." *Coronavirus Disease 2019 (COVID-19).* Accessed November 2020. https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html.

[17] Centers for Disease Control and Prevention. 2020. "Protect Yourself." *Coronavirus Disease 2019 (COVID-19).* Accessed November 2020. https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html.

[18] National Center for Health Statistics. 2020. "Provisional Death Counts for Coronavirus Disease 2019 (COVID-19)." *Centers for Disease Control and Prevention*. Accessed October 2020. https://www.cdc.gov/nchs/nvss/vsrr/covid_weekly/index.htm#Comorbidities.

[19] World Health Organization. 2020. *What we know about the Long-term effects of COVID-19*. Accessed December 2020. https://www.who.int/docs/default-source/coronaviruse/risk-comms-updates/update-36-long-term-symptoms.pdf?sfvrsn=5d3789a6_2.

Because efforts for social distancing and prevention of virus spread have mostly been implemented at the state level, since the appearance of the virus in the US in the early Spring of 2020, the rankings of case count by state have varied based on the intensity of enforcement and city shut downs at a given point in time. In comparison to other countries, the US leads the globe in counts of COVID-19 cases and deaths[20], which includes disproportionately higher rates among non-white Americans (Figure 1).

Rate ratios compared to White, Non-Hispanic Persons	American Indian or Alaska Native, Non-Hispanic persons	Asian, Non-Hispanic persons	Black or African American, Non-Hispanic persons	Hispanic or Latino persons
Cases[1]	2.8x higher	1.1x higher	2.6x higher	2.8x higher
Hospitalization[2]	5.3x higher	1.3x higher	4.7x higher	4.6x higher
Death[3]	1.4x higher	No Increase	2.1x higher	1.1x higher

Figure 1. COVID-19 Hospitalization and Death by Race/Ethnicity[3]

Evidence for links between race, environmental quality and health – case studies

In 1968, consistent with the period of the Civil Rights movement, the Memphis Sanitation Strike by African American garbage workers protesting for equitable work environments marked the beginning of the environmental justice movement which was

[20] Statista. 2020. "Number of novel coronavirus (COVID-19) deaths worldwide as of December 7, 2020, by country." *State of Health*. Accessed December 2020. https://www.statista.com/statistics/1093256/novel-coronavirus-2019ncov-deaths-worldwide-by-country/.

started by “individuals, primarily people of color, who sought to address the inequity of environmental protection in their communities”[21]. Since then, a plethora of academic studies and data analysis have shown that hazardous environmental quality, health and race are inextricably linked[22,23], such as the 1987 report, “Toxic Waste and Race in the United States” released by the United Church of Christ Commission for Racial Justice, which was an essential document for first comprehensively and publicly, highlighting the disproportionate exposure of people of color to toxic waste sites and facilities in the country[24]. In 2007, a follow-up report titled “Toxic Wastes and Race at Twenty, 1987-2007: Grassroots Struggles to Dismantle Environmental Racism in the United States” exposed that despite the prevalence of knowledge concerning environmental injustice that had become available in the twenty years following the preliminary report, disparities continued to exist, “people of color are found to be more concentrated around hazardous waste facilities than previously shown”[25], and that

[21] United States Environmental Protection Agency. 2020. “Environmental Justice Timeline.” *Environmental Justice*. Accessed December 2020. https://www.epa.gov/environmentaljustice/environmental-justice-timeline#:~:text=The%20environmental%20justice%20movement%20was,families%2C%20their%20communities%20and%20themselves.

[22] Morello-Frosch, R., & Jesdale, B. M. 2006. “Separate and unequal: residential segregation and estimated cancer risks associated with ambient air toxics in US metropolitan areas.” *Environmental health perspectives*, *114*(3), 386-393.

[23] Brender, J. D., Maantay, J. A., & Chakraborty, J. 2011. “Residential proximity to environmental hazards and adverse health outcomes.” *American journal of public health*, *101*(S1), S37-S52.

[24] United Church of Christ. Commission for Racial Justice. 1987. *Toxic wastes and race in the United States: A national report on the racial and socio-economic characteristics of communities with hazardous waste sites*. Public Data Access.

[25] Bullard, R. D., Mohai, P., Saha, R., & Wright, B. 2008. “Toxic wastes and race at twenty: Why race still matters after all of these years.” *Environmental Law*, 371-411.

there still existed major barriers and gaps in the implementation of initiatives and policies that protect vulnerable populations for environmental injustice[26]. Specifically concerning air quality and particulate matter exposure, a 2017 study found that "for PM of 2.5 micrometers in diameter or less, those in poverty had 1.35 times higher burden than did the overall population, and non-whites had 1.28 times higher burden,"[27] a pattern that was reflected at the national, state and county levels[27].

In the face of the COVID-19 that is disproportionately affecting BIPOC (Figure 1), environment and health professionals continue to further study the existing evidence links between environmental air quality and health in the context of a respiratory disease pandemic, finding correlations between hazardous amounts of air pollution, high per-capita COVID-19 case rates, and high concentrations of non-white populations[28,29,30]. In addition to disproportionate exposure to unhealthy environments, inequalities concerning the upstream and downstream determinants of health – such as income and education – also play a role in access to healthcare and ability to prevent

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[26] University of Michigan News. 2007. "Toxic waste and race: Report confirms no progress made in 20 years." Accessed December 2020. https://news.umich.edu/toxic-waste-and-race-report-confirms-no-progress-made-in-20-years/#:~:text=The%20new%20report%2C%20"Toxic%20Wastes,are%20not%20equally%20protected%20by.

[27] Mikati, I., Benson, A. F., Luben, T. J., Sacks, J. D., & Richmond-Bryant, J. 2018. "Disparities in distribution of particulate matter emission sources by race and poverty status." *American journal of public health*, *108*(4), 480-485.

[28] Terrell, K. A., & James, W. 2020. "Racial Disparities in Air Pollution Burden and COVID-19 Deaths in Louisiana, USA, in the Context of Long-Term Changes in Fine Particulate Pollution." *Environmental Justice*.

[29] Public Health Institute. 2020. "Study Probes Links Between Air Pollution, Race and COVID-19." Accessed December 2020. https://www.phi.org/press/study-probes-links-between-air-pollution-race-and-covid-19/.

[30] 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." *medRxiv*.

and recover from sicknesses among BIPOC[31]. Brandt et al 2020 reports that a mix of environmental, socioeconomic and racial factors contribute to COVID-19 fatality rates including "crowded living conditions, multigenerational homes,"[32] "limited access to health care and healthy foods"[32], "working in low paying 'essential' jobs"[32], "chronic exposure to air pollution"[32] and "structural racism[32]."

Conclusion: A Research Agenda/Gaps

In a 2017 article, Laura Pulido argues that "environmental racism is a constituent of racial capitalism"[33], that, in summary, the institution of the United States with its combined morals of production and capitalism has resulted in a society that values profit over environmental quality and whiteness over minority well-being. These themes are clearly reflected in academic literature related to environmental justice and health. Acknowledging the widespread knowledge that exists in this field and the recent initiations of research specifically related to the ongoing pandemic and environmental injustice, this study choses to expand this area of research by specifically looking at the geospatial relationship of air quality, COVID-19, race, and socioeconomic status within counties of Georgia. Air quality studies that look at data at

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[31] Centers for Disease Control and Prevention. 2020. "Social Determinants of Health: Know What Affects Health." Accessed December 2020. https://www.cdc.gov/socialdeterminants/about.html.

[32] Brandt, E. B., Beck, A. F., & Mersha, T. B. 2020. "Air pollution, racial disparities, and COVID-19 mortality." *Journal of Allergy and Clinical Immunology*.

[33] Pulido, L. 2017. "Geographies of race and ethnicity II: Environmental racism, racial capitalism and state-sanctioned violence." *Progress in Human Geography*, *41*(4), 524-533.

the state or smaller level are particularly important given that both EPA State Implementation Plans, and many COVID-19 related restrictions and procedures, are implemented on a state level. The results of this data analysis, and similar ones for other entities, will be an important basis for informing policy decisions and interventions related to air quality, environmental management and public health at both the federal and state level, given that air movement is not limited by county or state boundaries.

METHODS

Data

For this study, analyzing if there is a relationship between COVID-19, race, and socioeconomic factors, data was processed and visualized using a combination of statistical methods in ArcMap, Microsoft Excel, and Tableau Public. Population demographic data and estimates at the county level were obtained from the 2019 US Census Bureau Population Division, publicly available for download on the Georgia Governor's Office of Planning and Budget website[34]. COVID-19 data was gathered from the Georgia Department of Public Health on February 22, 2021, including COVID-

[34] US Census Bureau Population Division. 2019. "County Population Estimates 2019." Accessed February 2021. https://opb.georgia.gov/census-data/population-estimates.

19 death rates and case rates per 100,000 people in each county up to that date[35]. Race and age data was gathered from the Georgia Governor's Office of Planning and Budget 2020 Population Projections[36], poverty data was gathered from the Small Area Income and Poverty Estimates for 2019[37], and income data was collected from the 2015 – 2019 American Community Survey Estimates via Social Explorer[38].

Surface-level outdoor PM2.5 air quality satellite data for the year 2018 was gathered from via Washington University in St. Louis, Atmospheric Composition Analysis Group,[39] and the raster data values were averaged by county using ArcMap Zonal Statistics function in $\mu g/m^3$. In addition, the Environmental Protection Agency's 2014 Total Respiratory Hazard Quotients (RHQ) which is a measure of the likeliness of noncancer health effects given exposure to a certain substance where a RHQ less than one means that adverse cancer effects are not likely, and a RHQ greater than one reflects an increase in hazard potential by an unknown amount[40]. The total RHQ is a sum of the RHW for forty-three air pollutants by Georgia tracts which was averaged in

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[35] Georgia Department of Public Health. 2021. "Georgia Department of Public Health Daily Status Report." Accessed February 2021. https://dph.georgia.gov/covid-19-daily-status-report.

[36] Georgia Governor's Office of Planning and Budget. "2020 Population Projections." Accessed February 2021. https://opb.georgia.gov/census-data/population-projections.

[37] US Census Bureau. 2019. "Small Area Income and Poverty Estimates." Accessed February 2021. https://www.census.gov/programs-surveys/saipe.html.

[38] Us Census Bureau. 2019. "2015 – 2019 American Community Survey Estimates." Accessed February 2021. https://www.socialexplorer.com/data/ACS2019_5yr.

[39] Atmospheric Composition Analysis Group. 2018. "Surface PM2.5." Washington University in St. Louis. Accessed February 2021. https://sites.wustl.edu/acag/datasets/surface-pm2-5/#V4.NA.03.

[40] US Environmental Protection Agency. 2018. "2014 National Air Toxics Assessment." Accessed February 2021. https://www.epa.gov/national-air-toxics-assessment/2014-national-air-toxics-assessment.

ArcMap by county using the summarize tool and was also used as a variable due to the fact that pre-existing respiratory conditions may contribute to the susceptibility of a person to COVID-19[8].

Analysis

Simple and multiple linear regression analyses, statistical methods which are used to predict the value of one variable based on another and are specifically beneficial when it is necessary to control for variables included in the model, were performed in Microsoft Excel and Tableau Public to evaluate the relationship between the dependent variables of COVID-19 death and case rates, with the independent variables of air pollution (2014 Respiratory Hazard Quotient and 2018 PM2.5 County Averages) and the following control variables that may be related to COVID-19 occurrences: percent population Black, median household income, percent population 65 and older, and percent population in poverty[3]. Specifically, air quality and income factors serve as policy variables because of their ability to be influenced by legislation and regulations. A statistically significant correlation is represented by a P value less than or equal to 0.05. Limitations of regression analyses include the assumption that data is normally distributed and its sensitivity to collinearity and outliers in datasets that may skew results. To avoid issues of collinearity, related variables, such as poverty and median income, or PM2.5 averages and RHQ, were not included simultaneously in regression models. In addition, outliers were removed from models when identified in results. The methods used are loosely based off those of similar analysis done by Terrell & James, 2020[28] which examined the relationship between COVID-19 death rates and air pollution in parishes within "Cancer Alley," Louisiana. All of the analyses were done at the county level due to the limitations of the COVID-19 data. The analyses findings are presented in a series of regression tables, charts and maps.

RESULTS

Simple Linear Regression Models

The average death rate of the 159 counties in Georgia was 188.4 per 100,000 people, with a minimum of 43.6 in Quitman county with a Black population of 48.5%. The maximum death rate of 659.1 was found in Hancock County, which was more than double of the next largest death rate and also had the largest black population of 70.9%. In general, regressions performed using death rates resulted in the most significant values, compared to case rates, for the counties in Georgia. The connection between percent population Black and COVID-19 death rates was apparent; as expected, percent population Black alone had a positive significant relationship to 139.78 COVID-19 death rates (Model 1, $p = 0.006$) with a coefficient of 1.42, meaning that for every one unit increase in percent Black population, death counts in the county would increase by 1.42; for example, a 20% increase in percent Black population would mean an additional 28.4 deaths in a county. Median household income alone also had a significant inverse relationship to death rate, as expected, with a coefficient of -0.004 (Model 2, $p < 0.0001$), where a $1,000 increase in median household income would result in decrease in deaths by 4.

Concerning air quality, RHQ had a positive significant relationship to percent Black population with a coefficient of 0.001, while PM2.5 2018 average did not (Model 3). Alone, RHQ had an insignificant relationship to county death rates, while PM2.5 2018 average had a surprisingly significant inverse correlation to death rate with a coefficient of -51.09, meaning that PM2.5 levels decreased with increasing death rates (Model 4). Dekalb, Cobb, Clayton and Fulton counties had the highest PM2.5 levels with relatively low death rates.

Multiple Linear Regression Models

Two multiple linear regression models were performed to analyze the relationship between COVID-19 death rates, air quality, and socioeconomic variables (Model 5 & 6) When compared to models involving poverty percentages, median household income seemed to be the most clear and significant predictor of death rate when regressed with other variables of air quality, percent Black population, and percent population 65 and over.

The two multiple linear regressions of (1) death rate with PM2.5 and the other socioeconomic variables, and (2) death rate with RHQ and the other socioeconomic variables resulted in significant p-values for the air quality factor, percent Black population, and median household income. Percent population 65 and over proved insignificant for both regressions. In both regressions, air quality and median household income had inverse relationships to COVID-19 death rates, while percent population Black had a positive relationship.

In Model 5, when regressed with RHQ, percent Black population had a coefficient of 1.04 and median household income had a coefficient of -.003. This means that if percent Black population were to increase by 20%, there would be an additional 20.08 deaths in a county. If median household income were to decrease by $1,000, there would be an additional 3 deaths in the county. Similarly in Model 6, when regressed with PM2.5 averages, a one unit increase in percent Black population would result in an increase in county deaths by 1.22, and a one unit decrease in median household income would result in .002 additional county deaths. Based on these coefficients, the impact of percent Black population on death rates is slightly stronger, and the impact of median household income on death rates is slightly weaker, compared to Model 5. Overall, the regressions did prove that there is a significant relationship between air quality and COVID-19 death rates, although the inverse relationship was unexpected.

RECOMMENDATIONS

As outlined in the beginning of this paper, the social determinants of health, including environmental and socioeconomic factors, play indirect and direct roles in health outcomes of individuals. The major significant findings of these regression analyses, that there is a relationship between race, income, air quality and COVID-19 death rates, are consistent with existing research on the topic. Specifically, this study prompts the general questions of (1) how to address the direct relationship between race, income and COVID-19 death rates in Georgia counties, and (2) why is there an inverse relationship between air quality and COVID-19 death rates in Georgia counties.

Air Quality

Moving forward towards an agenda for environmental justice, the results of this study calls for further investigation into the complex relationship between health outcomes, environmental conditions and socioeconomic factors. Specifically, it is recommended that further research be completed analyzing these relationships at a smaller scale within counties, such as census tract level, which may offer a clearer picture of trends to strengthen the push towards addressing environmental disparities within communities. Being that the values of these distinct variables vary between counties, such as differences between affluence and income, collaboration in gathering and analyzing data between municipal governments, research institutions, and other relevant organizations, would prove helpful in dissecting the complexities of the topic at large.

Furthermore, a detailed study looking into the major sources of air pollution within each county would allow for a better understanding of the relationship between socioeconomic variables and air quality. For example, speculating on the fact that Dekalb, Cobb, Clayton and Fulton counties had the highest PM2.5 levels with relatively low death rates and large overall populations compared to the rest of Georgia, calls for a further look into the relationship between total population size, urban density, air pollution sources (such as transportation and industry), affluence, and health outcomes that would be useful for better understanding environmental justice as it appears across areas of various densities and sizes.

Access to Healthcare

Addressing factors that contribute to the vulnerability of certain populations to COVID-19 infection and death should be a top priority of federal, state, and municipal government institutions. As exemplified in this study and others, the factors influencing vulnerability are complex, including interactions between race and income, and efforts to accommodate vulnerable populations during this pandemic will require cross sector, multi-scale collaboration, not limited to health, environment, design, economic, and policy professionals.

In the short term, health professionals should work to increase access to affordable healthcare within vulnerable communities, removing the barriers that often times prevent individuals from receiving the help they need – this includes COVID-19 related interventions such as expanding testing and vaccine sites at the county level, in addition to resources for other illnesses and injuries that may make one more vulnerable to having worsened side effects of the virus or may disrupt other factors that influence quality of life, such as income and ability to travel. In addition to affordable healthcare access, education is an essential piece of preventing the spread of infectious disease and relevant, science-backed information should be made available to students within school systems, in addition to the general public through various media channels. In the long-term, change towards more equitable healthcare systems can be achieved by building on and improving policies, such as the Affordable Care Act, through the creation of more low-cost public healthcare and insurance options, and lowering the costs of prescription drugs which would greatly increase access to healthcare related resources within the American population.

Economic Mobility

Reducing wealth disparities and increasing economic mobility is another essential piece to addressing the state of health within Georgia and other states. Concerning poverty and income, an immediate intervention during the COVID-19 pandemic is the distribution of stimulus checks by the federal government to the American population. Increasing the amount and frequency of these payments would be beneficial in providing low-income people immediate financial relief in the face of the pandemic. In addition, temporary eviction moratoriums implemented city-wide may also reduce financial burdens for renters during the length of the pandemic. Other long-term opportunities to disrupt the "health-poverty trap"[41] include increasing minimum wage values and enacting livable wage ordinances at the local level, along with the creation of affordable housing projects that remove some of the burdens of the cost of living on low-income individuals. In addition, strategies for improving economic mobility and building wealth that has historically been prevented among minority populations[42] include the distribution of microfinancing loans for small businesses and the creation community land trust models that provide affordable

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[41] Khullar, D., & Chokshi, D. A. 2018. Health, income, & poverty: Where we are & what could help. *Health affairs*, *4*. Accessed April 2021. https://www.rwjf.org/en/library/research/2018/10/health--income-and-poverty-where-we-are-and-what-could-help.html.

[42] Robert K. Nelson, LaDale Winling, Richard Marciano, Nathan Connolly, et al. "Mapping Inequality: Redlining in New Deal America." *American Panorama*, ed. Robert K. Nelson and Edward L. Ayers. Accessed April 2021. https://dsl.richmond.edu/panorama/redlining/#loc=5/39.1/-94.58&text=intro.

options for homeownership – these are tools can be implemented for long-term wealth creation within economically disadvantaged communities.

Healthy Communities

From the perspective of design and planning professionals, the environment plays an important role in health outcomes, so it is consequently necessary to strive towards addressing these built environment disparities that contribute to quality of life and well-being through meaningful design and policy interventions. For example, on the city level, the creation of widespread, reliable, and safe public transportation systems serves the benefit of offering affordable travel to economically burdened groups while also promoting the reduced use of single occupancy vehicles that contribute to air pollution. Within the home and workplace, designers should strive to create healthy environments that address issues such as air quality, injury prevention, and hazard reduction within building structures that can influence both physical and mental health. Greenspace accessibility, which can be implemented through municipal greenspace plans, also serves an important role in cities as it offers health benefits by promoting recreation, it creates public spaces for all members of communities to gather and socialize, while also serving as a potential tool for reducing pollution in both air and water and addressing urban heath islands[43].

CONCLUSION

Overall, the results of this study highlight the complex relationship between infectious disease, race, socioeconomic factors, and the environment. Specifically, the fact that Black and economically burdened populations face disparities when it comes to the COVID-19 pandemic is a reoccurring theme in the discussion of the historical, systemic racism and injustices in this country. Both long-term and short-term interventions are necessary to address the discrimination faced by minority and low-income communities in both the state of Georgia and the United States of America. These interventions will require completing detailed studies at finer geographic scales to better understand the intricacies of these relationships, in addition to collaboration between a range of industries including healthcare, environmental, design, and policy professionals working at all governmental and community levels.

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[43] Centers for Disease Control and Prevention. 2013. "Parks and Trails Health Impact Assessment Toolkit." Accessed April 2021. https://www.cdc.gov/healthyplaces/parks_trails/.

TABLES & FIGURES

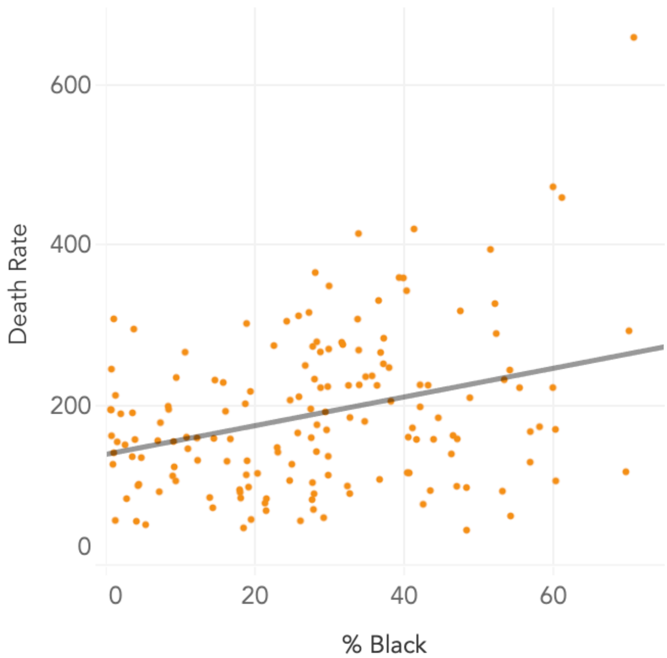
TABLE 1 – Summary of County Death Rates (per 100,000 people)

Count	159
Average	188.4
Minimum	43.6
Maximum	659.1
Median	169.4

MODEL 1

P-value: < 0.0001

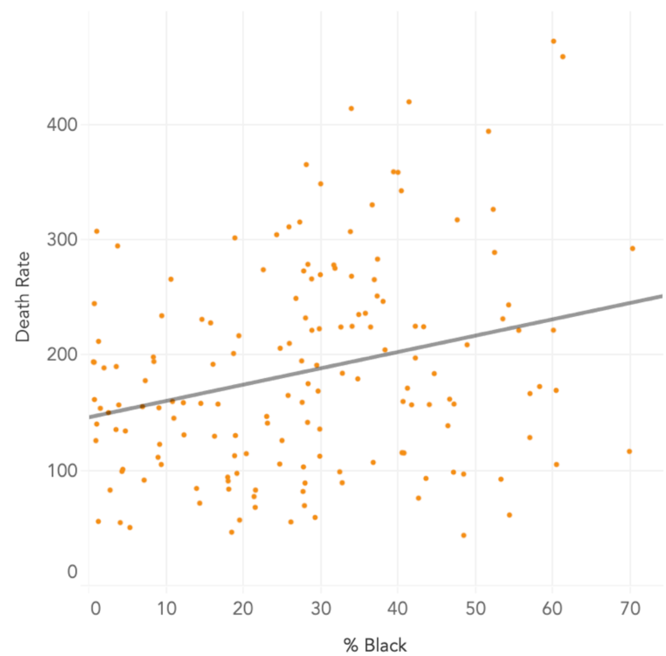
Equation: Death Rate = 1.78824*%Black + 138.227



(outlier removed)

P-value: 0.00062

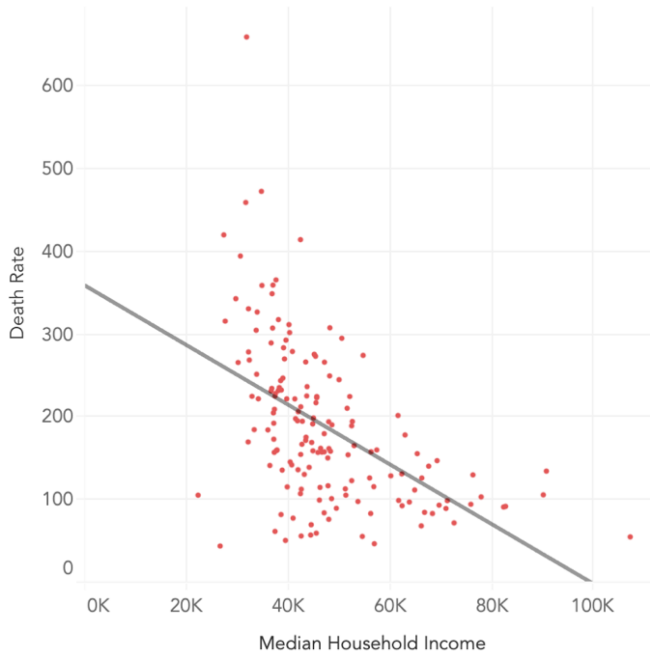
Equation: Death Rate = 1.41871*%Black + 146.008



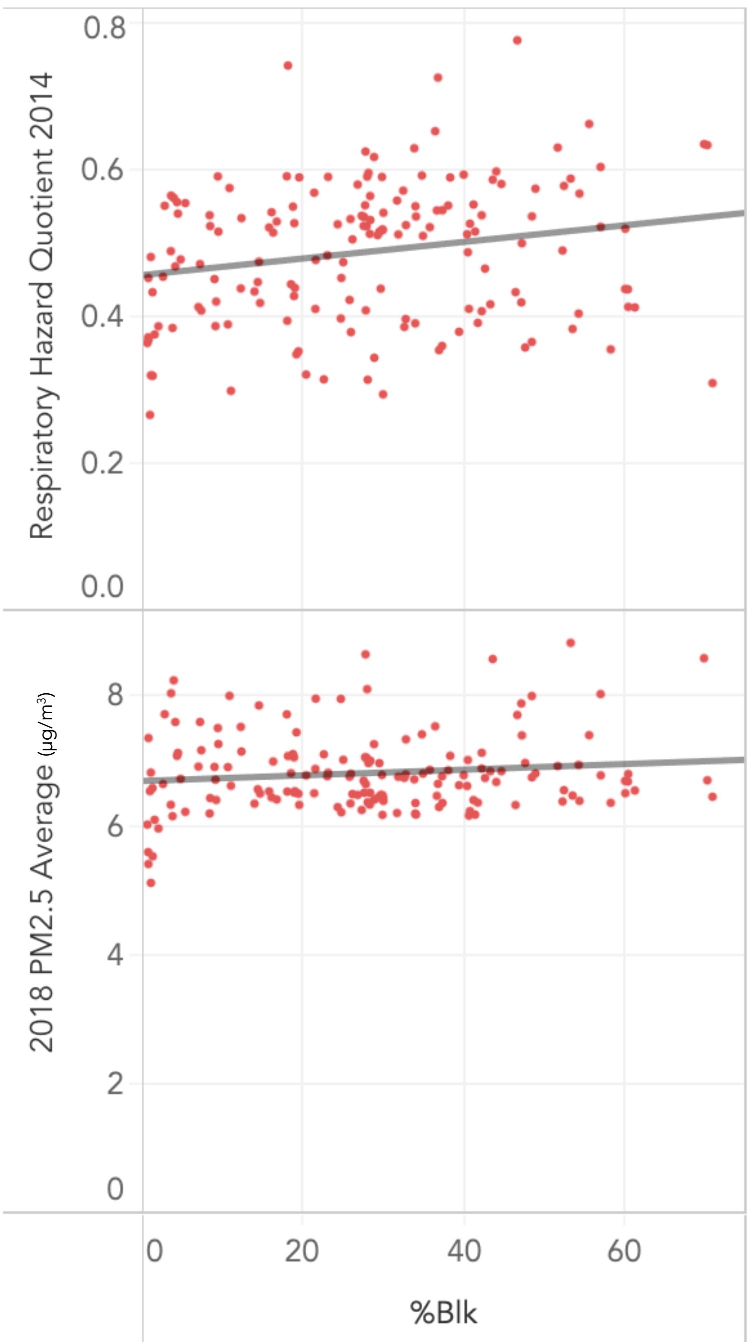
MODEL 2

P-value: < 0.0001

Equation: Death Rate = -0.00361037*Median Household Income + 358.951



MODEL 3



P-value: 0.00942243

Equation: RHQ2014 = 0.00113156*%BLK + 0.457058

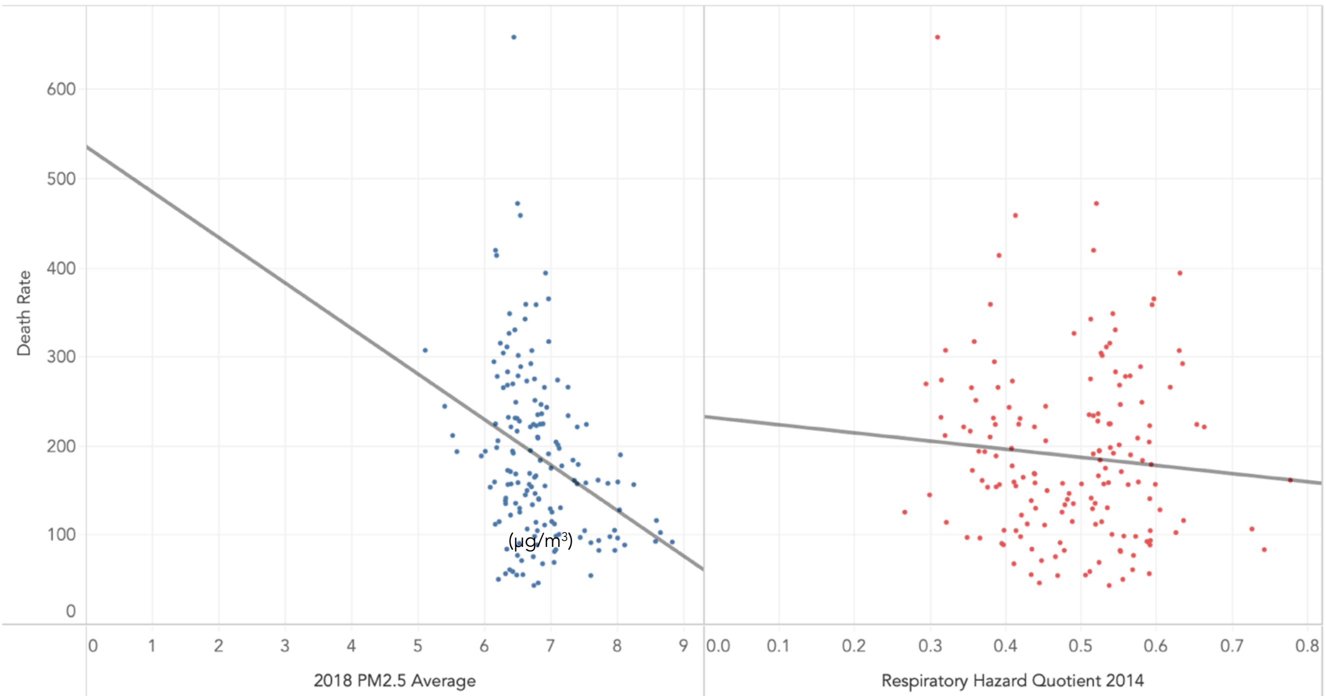
P-value: 0.11838

Equation: 2018PM2.5AVG = 0.00437195*%Blk + 6.68457

MODEL 4

P-value: < 0.0001
Equation: Deathrate = -51.0932*2018PM2.5AVG + 536.242

P-value: 0.259962
Equation: Deathrate = -91.2583*RHQ2014 + 233.044



MODEL 5

Dependent variable: COVID-19 county death rates per 100,000 people

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.549236347
R Square	0.301660565
Adjusted R Squ	0.283521878
Standard Error	82.43838151
Observations	159

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	452096.9811	113024.2453	16.6307832	2.38474E-11
Residual	154	1046597.359	6796.086746		
Total	158	1498694.34			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	355.9413674	57.19386602	6.223418562	4.39854E-09	242.9555681	468.9271668	242.9555681	468.9271668
RHQ2014	-143.2568877	72.14191354	-1.985765011	0.048834617	-285.7723764	-0.741399024	-285.7723764	-0.741399024
%BLK	1.035177389	0.421571768	2.455518769	0.015180332	0.202367396	1.867987382	0.202367396	1.867987382
MEDHHINC	-0.003154867	0.000524544	-6.014488434	1.26227E-08	-0.004191098	-0.002118635	-0.004191098	-0.002118635
%65+	1.138965559	1.16700366	0.975974282	0.330607808	-1.166436235	3.444367353	-1.166436235	3.444367353

MODEL 6

Dependent variable: COVID-19 county death rates per 100,000 people

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.55228825
R Square	0.30502231
Adjusted R Sq	0.28697094
Standard Erroi	82.2397164
Observations	159

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	457135.213	114283.803	16.8974619	1.6622E-11
Residual	154	1041559.13	6763.37096		
Total	158	1498694.34			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	445.516157	87.7437703	5.07746767	1.0909E-06	272.179387	618.852927	272.179387	618.852927
2018PM2.5AV	-28.825839	13.286102	-2.1696235	0.03156875	-55.0723748	-2.57930322	-55.0723748	-2.57930322
%BLK	1.21655455	0.43936215	2.76891066	0.00631561	0.34859986	2.08450924	0.34859986	2.08450924
MEDHHINC	-0.00242671	0.00061839	-3.92423807	0.0001308	-0.00364833	-0.00120509	-0.00364833	-0.00120509
%65+	0.99397792	1.17560263	0.84550501	0.39914069	-1.32841104	3.31636687	-1.32841104	3.31636687