Summer 8-14-2020

Examining the Intersection of Environmental Justice, Chronic Disease, and Pandemics; How a Mobile Health App Could Improve Health Outcomes and Inform Policy

Jessica Snow
snowjessica26@gmail.com

Examining the Intersection of Environmental Justice, Chronic Disease, and Pandemics; How a Mobile Health App Could Improve Health Outcomes and Inform Policy

Jessica A. Snow

MPH Candidate 2020

University of San Francisco

Table of Contents

Abstract

The purpose of this paper is to analyze the intersection of environmental justice, chronic disease and illness, and pandemics. The inequitable distribution of polluting factories, landfills, and hazardous waste sites have been a long-standing concern in the field of environmental justice. Local zoning codes and land use policies have been tools for segregating people and concentrating pollution in low-income communities and communities of color. Many studies have found that pollution varies among racial and minority groups, and the burden of pollution is not one that is evenly shared. Communities of color and low-income communities are disproportionately affected by air pollution and experience higher rates of illness associated with increased exposure. In addition to increased rates of chronic disease, people of color and low-income communities are disproportionately affected by respiratory pandemics, including influenza and Coronavirus (COVID-19). COVID-19 has highlighted the inequities that these vulnerable communities face and the compounding effects that air pollution can have on human health. This paper argues that current public health infrastructure does not capture the necessary data to inform policy and improve outcomes for those that are most affected. It calls for the development of a mobile health application to gather community level data, inform and educate residents on the environmental issues in their area, and act as a resource for both individuals and government entities during a pandemic.

Keywords: environmental justice, environmental racism, air pollution, chronic disease, pandemics, structural inequalities, racial health disparities, mobile health application

Examining the Intersection of Environmental Justice, Chronic Disease, and Pandemics; How a Mobile Health App Could Improve Health Outcomes and Inform Policy

The concept of environmental justice gained momentum in the 1980's after studies from the General Accountability Office and the United Church of Christ were published. These studies suggested that low income and minority communities were being disproportionately exposed to and affected by environmental hazards (Gray, 2010). Just as the effects of pollution disproportionately affect the most vulnerable communities, including black and low-income communities, chronic disease and respiratory pandemics are doing the same. Black Americans are more likely to die of most cancers, including prostate, stomach, and breast cancer, than their white counterparts (National Cancer Institute, 2019). Black adults are also more likely than white adults to suffer from hypertension, diabetes, heart disease, and obesity CDC, 2019).

Areas of high pollution have a higher rate of coronavirus deaths than low polluted areas, and black and Hispanic populations are more likely to live in these polluted areas than predominantly white populations. Epicenters for coronavirus are focused in areas of high pollution and large populations of people of color and low-income communities. These include New York, New Orleans, Detroit, Houston, Richmond, LA, and so on. Past influenza pandemics have affected this vulnerable population as well. Similarly to COVID 19, influenza targets the respiratory systems, making populations in highly polluted areas susceptible to decreased health outcomes. Of the 3 influenza pandemics during the 20th century, black Americans died at a 35% higher rate than their white counterparts. From 1999 to 2005, black communities had higher influenza and pneumonia mortality rates than all other populations (Hutchins et al, 2009). Racial gaps in relation to disease and illness highlight the intersecting inequalities that communities of color face in jobs, housing, and health. This evidence suggests there is a connection between chronic disease, COVID-19 and past pandemics, and the intersectional environmental crisis.

This paper will look at environmental pollution and its health impact on people of color and low- income communities. It will then analyze state COVID 19 data and other influenza pandemic data to determine the rates at which people of color are affected by these pandemics. The relationship between COVID 19 / pandemics and environmental pollution will then be examined in the context of the socio-ecological model and through the lens of intersectional environmentalism.

What is intersectional environmentalism and environmental justice?

Intersectional environmentalism, a relatively new concept emerging from the COVID-19 pandemic, refers to a more inclusive version of environmentalism that not only focuses on the protection of the planet, but on the protection of people as well. It identifies the ways in which injustices are done to marginalized communities and the Earth and brings social justice issues to the forefront. It is the understanding that racial inequities, urban and rural divides, poverty, and other social issues are all shaped by environmental injustices.

The environmental justice movement began in the 1980's in Warren County, North Carolina when tons of PCB-ridden soil was dumped into a landfill within a black community, despite the community's opposition. The community was worried the PCB's would leach into their water supply, so they protested the dump. These protests drew national attention, and so the environmental justice movement began. Cities and States started to notice that polluting factories were being placed in low income black communities that had little political or financial clout to protect them (Skelton & Miller, 2016). The term environmental racism was soon coined and refers to the institutional rules, regulations, and policies that target communities of color and leave them disproportionately affected by environmental hazards.

A more recent example of environmental injustice is the water crisis in Flint Michigan, whose population is largely black. The City of Flint's water source was changed to the Flint river in 2014 in an attempt to save the city millions of dollars. The river had been a repository for industrial waste from the city's once booming factories. Many residents feared the quality of water was poor and opposed the transition. Residents started to get sick and sent correspondence to their state leaders asking for change. It was noted that city and state leaders acknowledged there were chemicals in the water known to harm humans, but it was not a health concern. Reports soon started showing increased levels of lead in children, and still the response to clean up the water supply was very slow (Eligon, 2016).

There are many structural inequalities that are a major reason we are seeing these health disparities and environmental conditions in communities of color. There are different patterns of land use, highways and roadways with frequent traffic and congestion, and industrial activity. Environmental justice issues are multilayered. Therefore, the approach to tackling these issues must also be multilayered. One of the recommendations is to increase investments into robust data collection methods and infrastructure, including an all-encompassing mobile health application (mHealth app). Data systems used by States and Public Health Departments do not utilize technology to its full potential, and infrastructure for these systems are severely underfunded. Resources need to be allocated so that these data systems can modernize their technology and create up to date, real time reporting capabilities. Additionally, with an increased quality of data and reporting, policies can be better informed to help vulnerable communities.

Background

Humans are affected by environmental hazards every day. We live in communities that share space with polluting power plants and toxic chemical facilities. Chemicals leach out and pollute the water, air, and land we need to eat, drink, and breathe. It is often the communities that contribute the least to this pollution that bear the biggest burden (Tessum, 2019). Marginalized communities and communities of color are disproportionately affected by environmental pollution compared to white Americans.

As mentioned earlier, Flint, a predominantly black community, has been forced to use and drink contaminated water so the city could save money. In Greeneville, Mississippi many residents, predominantly black and Hispanic, live within a mile of a Superfund site (Bergman, 2019). A Superfund site is a manufacturing facility, processing plant, landfill, or mining site that contains hazardous waste being dumped, left in the open, or has been mismanaged (epa.gov). The chemicals and hazardous waste at these sites pose a very serious health risk to the public. Some risks associated with the chemicals at these sites include cancer, birth defects, nerve damage, liver damage, and developmental and behavioral issues in children (US GAO, 1995). Throughout the United States white Americans produce more air pollution through their consumption of goods and services but experience 17% less air pollution exposure than they create. Meanwhile black Americans consume less and produce less air pollution but experience 56% more exposure than they cause (Tessum, 2019). In Figure 1 below, it shows that the black population creates much less pollution than the population average. However, they are exposed to far more pollution than the average American. The trend is very similar for Hispanic populations. On the other hand, white Americans produce more pollution than the population average, but are not as exposed as populations of color. This paper will primarily focus on air pollution due to its known negative health outcomes and the implications it has on past pandemics, COVID-19, and unknown future pandemics.

Figure 1

Average Pollution Inequality by Racial Groups

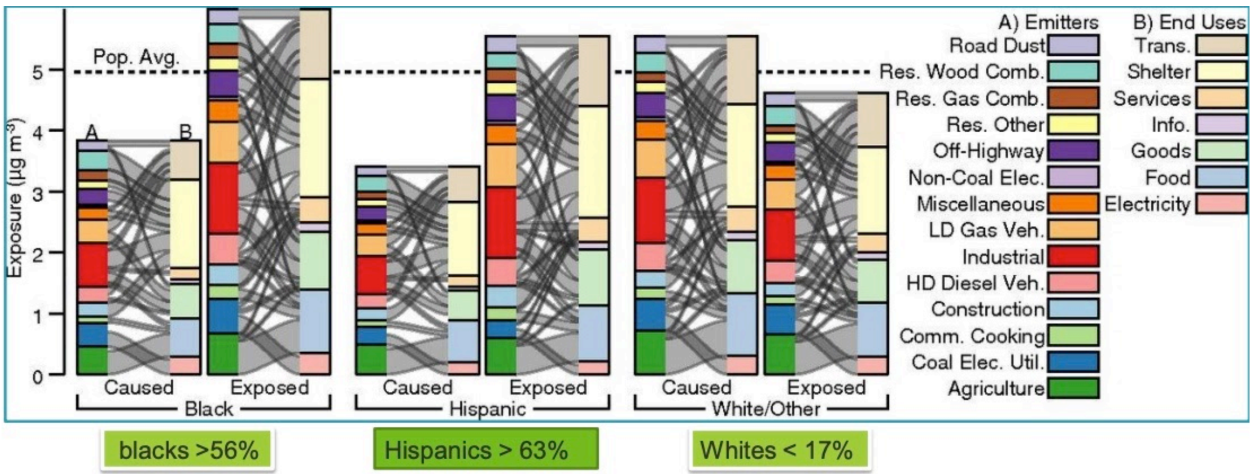


Figure was obtained from Tessum et al, 2019.

Air Pollution

In the United States, the Environmental Protection Agency (EPA) is the primary agency tasked with protecting the environment and ensuring American's have access to clean air, water, and land. They work with the government to develop and enforce regulations, complete scientific studies, and provide financial assistance to outside partners. More specifically and in regard to air pollution, they monitor air quality standards and pollutants in the air (EPA, n.d.). One concern of the EPA is fine particulate matter, or particles that are less than 2.5 micrometers. However, there are other types of pollution that are harmful to both people and the earth. These include ground level ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, lead, and hazardous air pollution (APHA, 2017).

The highest levels of air pollution typically occur in crowded urban areas in close proximity to industrial and commercial factory sources. The largest source of air pollution is electrical power generation with the use of fossil fuels, such as coal. Of the 1,400 coal and oil fuels electric power plants in the United States, very few have advanced pollution control standards and equipment. These power plants emit carbon dioxide, sulfur dioxide, mercury, chromium, arsenic, and nitrogen oxides (APHA, 2017). Another main source of air pollution are mobile sources, or transportation sources. These include cars, planes, trains, and buses, and account for almost half of all air pollution (National Park Service, 2018). In urban locations, nearly 45 million Americans live within close proximity to a major polluting road, airport, or railroad (APHA, 2017). Other smaller sources of pollution include livestock, fertilizers, and natural sources like wildfires and dust (National Park Service, 2018).

State by State Comparisons

People of color and low-income communities experience higher rates of air pollution exposure than their white counterparts (Bell & Ebisu, 2012). Black families are 75% more likely to live in a fenceline community, or a place bordering a polluting factory or refinery, compared to the average American. They are also exposed to air that is almost 40% more polluted, when compared to their white counterparts (Fleischman & Franklin, 2017).

California. On average, African American, Latino, and Asian Californians are exposed to more pollution from cars, trucks, and buses than white Californians. These groups are exposed to pollution 43, 39, and 21 percent higher, respectively, than their white counterparts (Union of Concerned Scientists, 2019). The lowest-income households live where pollution is 10 percent higher than the state average. Those with the highest incomes live where pollution is 13 percent below the state average. Households earning less than $20,000 a year and people who don't own cars suffer vehicle pollution levels about 20 percent higher than the state average (Union of Concerned Scientists, 2019).

Massachusetts. In Massachusetts, urban areas have greater densities of particulate matter pollution sources, creating inequitable exposure. These urban areas are made up of predominantly low-income communities of color. Black households or households with an income less than $20,000 were the most burdened and exposed communities within the entire state of Massachusetts (Rosofsky et al, 2017). In the Boston area, 45% of Black residents live in areas that are highly polluted, compared to less than 30% of white residents (Gately & Reardon, 2020).

New York. In New York state, mobile sources are the leading sources of pollution. Two million black residents, which equates to 74% of the total black population in New York, live in an area where pollution from mobile sources are higher than the state's average. Compared to their white counterparts, black residents are exposed to 72% more pollution. Meanwhile, more than two-thirds of white residents in New York state live in areas that have levels of pollution below the state average. The state's most polluted area is West Bronx, New York City, and it is composed mostly of people of color. Residents in this area are exposed to pollution that is up to 270 percent higher than the state's average (Union of Concerned Scientists, 2019).

Negative Health Outcomes

Fine particulate air pollution is responsible for the vast majority of the 3 to 4 million annual deaths attributed to air pollution worldwide. Studies have also shown that the negative health effects of air pollution are similar to the negative health effects of smoking tobacco products (Landrigan et al, 2018). Air pollution from fine particulate matter emitted from the burning of fossil fuels and automobile exhaust specifically accounts for approximately 100,000 deaths each year in the United States, and disproportionately impacts communities of color located in closer proximity to sources of air pollution (Lawton, 2020). Additionally, fine particulate matter contributes to climate change, which increases the need for heat and air conditioning and leads to more air pollution (APHA, 2017).

Chronic Disease and Illness. This increase in exposure to air pollution can lead to many negative health outcomes for both adults and children. According to WHO, exposure to air pollution is linked to heart disease, stroke, COPD, lung cancer, and acute respiratory infections in children. It accounts for 29% of death and disease from lung cancer, 24% of all deaths from stroke, and 43% of all death and disease from COPD (WHO, n.d.). Short-term exposure to increased levels of pollution can worsen lung and heart illnesses, cause asthma attacks, and lead to both increased hospitalizations and mortality from cardiovascular diseases (Orellano et al. 2017; Pope and Dockery 2006). In both children and adults, short and long term exposure to air pollution can lead to reduced lung function, respiratory infections, and aggravated asthma (WHO, n.d.).

Pandemics. In addition to chronic disease and illness, evidence has shown that there is a relationship between air pollution and respiratory pandemics. During the 2003 Severe Acute Respiratory Syndrome (SARS) outbreak, locations within China that experienced high levels of long-term air pollution had fatality rates 71% higher than locations with low pollution. More shockingly, with moderate levels of long-term exposure to air pollution, fatality rates were 126% higher than those with low exposure (Wu et al, 2020). Studies have also found that exposure to air pollution was associated with increased mortality during the influenza pandemic in 2009 (Morales et al, 2017). There is also a link between air pollution and the 1918 Spanish flu, suggesting that poor air quality was a cause of mortality during that pandemic. This study found that cities that utilized coal more frequently had tens of thousands more deaths than cities that did not use coal (Clay et al, 2018).

During the current COVID pandemic, connections are still being drawn to increased risk of illness and air pollution. Risk factors for severe cases of COVID-19 largely overlap with the list of chronic diseases that are exacerbated by chronic exposure to air pollution, including diabetes, heart diseases, asthma, lung cancer, and chronic obstructive pulmonary disease (CDC, 2020). A nationwide study done by Harvard in April 2020 found that a small increase in long term exposure to air pollution leads to a large increase in COVID-19 death rate. People living in a county with decades of high levels of particulate matter were 15 % more likely to die of COVID than counties with one unit less of particulate matter. This study also found that if Manhattan, New York had lowered its particulate matter level but one unit over the past 20 years, by April 2020 they could have seen nearly 250 less deaths due to COVID-19 (Wu et al, 2020).

Racial Disparities. As mentioned previously, low-income and black communities are more likely to live in areas of high pollution than predominantly white communities. Air pollution has shown to be a cause of mortality during pandemics, as well as a risk factor for chronic disease. This is where the connection should be drawn between air pollution, environmental justice communities, and increased rates of illness and death (Figure 3). Of the 3 influenza pandemics during the 20th century, black Americans died at a 35% higher rate than their white counterparts. From 1999 to 2005, black communities had higher influenza and pneumonia mortality rates than all other populations (Hutchins et al, 2009).

Figure 3

Health Status in U.S Racial Groups

	White	African Americans	Hispanic	Asian
Cause of Death	Age-adjusted Death rates (per 100,000)			
Heart disease	165.5	203.1	113.9	85.0
Coronary heart disease	101.2	114.8	75.3	55.3
Stroke	35.4	50.9	30.2	28.5
Cancer	170.9	194.2	115.2	102.6
Diabetes mellitus	18.6	38.2	25.1	15.1
COPD	41.8	24.7	15.6	10.3
Asthma	8.2	22.3	7.8	-
Pneumonia/Influenza	15.1	16.3	12.8	12.9
HIV infection	0.9	8.6	2.0	0.3
Infant mortality (/1000)	5.1	11.1	5.0	4.1
Life expectancy at birth	78.9	75.1	81.6	85
HIV mortality (/1000)	18	21	14	
COVID-19 mortality	30.2	70.0	34	29

Note. This image was obtained from a webcast titled Air Quality and COVID-19: Connections, Health Impacts, and Racial Disparities. https://www.american.edu/spa/cep/air-quality/index.cfm

These racial disparities are still very present during COVID 19. Nationwide, black Americans are dying at a rate 2.5 times higher than white people. In Wisconsin, 24% of people who have died are black even though they make up only 6% of the state's population. In Tennessee, 35% of people that have died are black and they only make up 15% of the population. South Carolina shows similar trends; almost half of the deaths are black, but they only make up 27% of the population. Many other states show similar disparities, including Michigan, New York, Louisiana, Mississippi, Kansas, Illinois, and Maryland (Covidtracking.com).

At the county levels, these disparities become even more stark. For example, in New York, neighborhoods with the highest number of cases were low income communities. Of the ten zip codes with the highest death tolls in New York City, eight of them are predominantly black and Hispanic populated. In Manhattan, a predominantly white borough with an average income of $157,000, 1 in 100 people contracted the illness. Comparatively in the Bronx, Queens, or Brooklyn with an average income of $54,000 and higher rates of black communities, 1 in 23 people contracted the illness (New York Times, 2020). In Louisiana, there is a stretch of land between New Orleans and Baton Rouge known as Cancer Alley. It goes along the Mississippi River, and is predominantly populated by black Americans. It got its name in the early 1990's because it is so polluted from chemical plants that line the river that residents living there became 95% more likely to get cancer than other American's (Karlson, 2020). Two Parish's line the river in this area, St. Charles and St John. Both of those areas have some of the highest rates of infection and death from COVID than any other Parish in the state (New York Times, 2020).

Structural Inequalities

There are many structural inequalities that lead to such health disparities among low-income communities and communities of color. A history of redlining and current environmental racism have put black Americans at an increased risk for disease and death. Environmental racism is not a new concept. It was first coined in studies about toxic waste sites and dumping in the early 2000's. It now encompasses all systems that produce and perpetuate inequalities in exposure to any and all environmental pollutants (Berkovitz, 2020).

Redlining. Redlining began in 1933 when the federal government started a program that aimed to prevent foreclosures due to the depression. Maps were generated and then neighborhoods were categorized into foreclosure risk groups. Neighborhoods that were predominantly black and immigrant were categorized as hazardous and outlined in red. Homes with higher property values and less people of color were categorized as low risk. Residential redlining enabled racial segregation, depreciated the value of the homes in those neighborhoods, and made it nearly impossible for those communities to accumulate wealth (Nardone, 2020).

This practice of redlining has had lasting effects on the current generations. Previously redlined communities are often low-income communities of color. They experience high poverty, high unemployment rates, and higher levels of pollution. Historically redlined census tracts have significantly higher rates of emergency department (ED) visits due to asthma. Census tracts that were previously redlined had ED visits 2-4 times higher than tracts that were not. (Nardone et al, 2020). For many respiratory pandemics, including influenza and COVID, asthma is a risk factor for increased complications (Lee et al, 2018 & CDC, 2020). This suggests that the discriminatory practice of redlining might have contributed to the racial health disparities that have become evident during recent pandemics.

Land Use and Zoning. In addition to redlining, other legislative policies such as zoning have affected the placement of toxic facilities, chemical plants, and highways. Communities of color and low-income communities were historically down zoned, meaning they went from residential to industrial zones, in order to allow for industry growth. Polluting industries sought after land that was cheap and less desired, so cities responded by de-zoning and setting up zoning codes to allow for industries to thrive in these communities (Baptista et al, 2019). Today racialized zoning takes the form of restricting residential mobility for low-income families desiring to live in higher-income neighborhoods that are generally less polluted. Local laws have turned to income-based criteria as a more subtle tool to enforce these discriminatory patterns of land use (Rothstein, 2017). For example, at the state level, Minnesota has Source of Income Laws. However, the law does not define Housing Choice Vouchers, or Section 8, as a source of income. Therefore, clients with Housing Choice Vouchers are not protected under Minessota state law. Other states that exclude Section 8 as a source of income are Oklahoma and Wisconsin (NMHC, 2019).

Another issue surrounding land use is single family home zoning, which protects neighborhoods of single-family homes from more dense development, highly trafficked roadways, factories, and urban pollution. Single family home zoning means that nothing else can be built there except for tidy single-family homes. This means apartment buildings and low-income housing, which are almost always multi-unit, are banned in these areas (Bui, 2019). This leads to increased development and crowding in already crowded and overly polluted neighborhoods. It also keeps property values lower. These zoning laws have cemented patterns in cities that separate housing types, so renters and low-income families are less likely to live among homeowners. This practice is also very far reaching; 75% of residential land is zoned strictly for single family homes (Bui, 2019).

Cumulative Impacts. Increased risk for these communities are paired with lower rates of being insured, lower median household incomes, and decreased access to health care (U.S Dept of Health and Human Services, 2019). Low socioeconomic status also increases the risk of premature death from air pollution among 13.2 million Medicare recipients, as seen in the largest examination of particle pollution-related mortality nationwide (Zeger et al, 2008). These vulnerable populations are also more likely to be essential low wage workers, exposing themselves to illness at a higher rate. Workplaces with high rates of exposure include farm and agricultural workers, who face inadequate safeguards, limited access to health care, and live in crowded housing conditions. Other jobs include grocery store clerks, fast food workers, janitorial staff, postal workers, drug store staff, and other service industry jobs. In these jobs, they experience a large pay gap, only earning 73 cents compared to their white counterparts' dollar.

Additionally, many of these jobs do not provide appropriate health benefits or sick leave, making these populations vulnerable and on the front line (Gould, 2020). Figure 4 illustrates the socio-ecological determinants of health that play a critical role in a person's chance of contracting or dying from COVID-19.

Figure 4

Socio-ecological Determinants of COVID-19

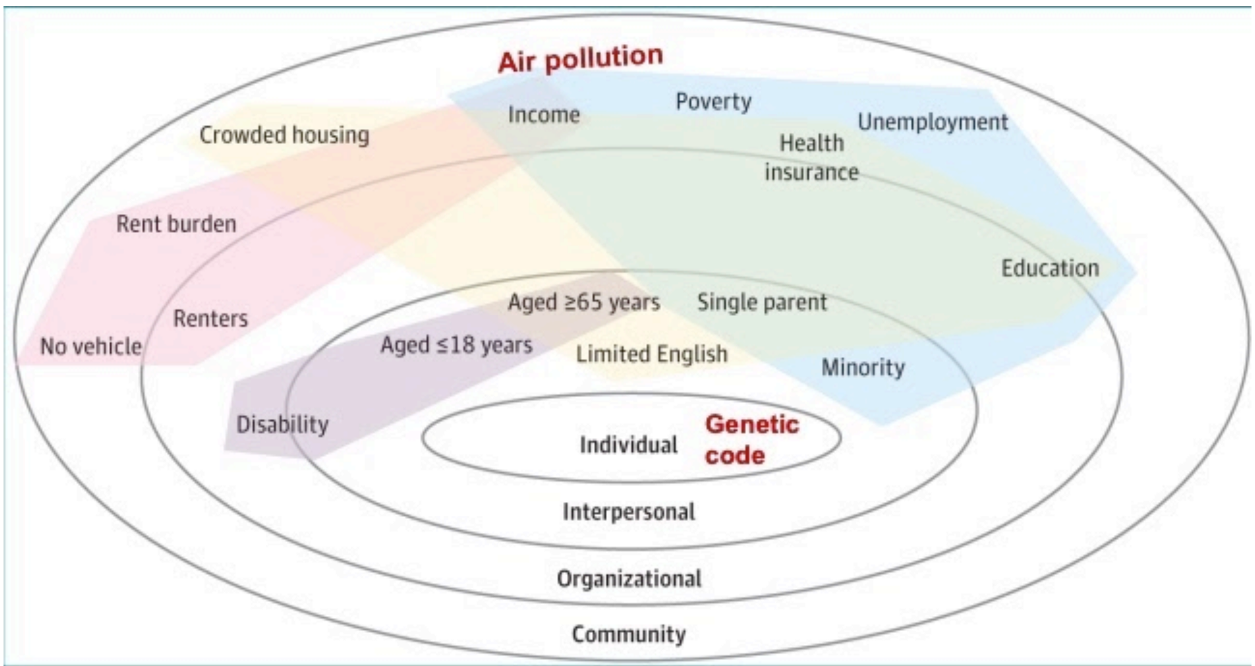


Figure was obtained from Kolak et al, 2020.

Current Policies and Regulations

Many state and federal laws have been put in place to address the air pollution and environmental justice crisis. In 1963 the federal government passed the Clean Air Act which established national standards for ambient air quality. It requires states to adopt enforceable plans to achieve these standards, and mandates they control emissions that drift across state lines and harm air quality down wind. This law has decreased concentrations of air pollutants dramatically since 1990 (epa.gov, 2020). Another federal law includes the National Environmental Policy

Act, which requires that federal agencies consider environmental justice in all projects and activities (epa.gov, 2019). A significant piece of California legislation pertaining to environmental justice and land use is Senate Bill 1000. It requires that all general plans incorporate an environmental justice element. Once jurisdictions identify environmentally disadvantaged communities (DACs), they are required to address a minimum of seven EJ-related issues in the general plan, including pollution exposure (Office of the Attorney General).

Many municipalities have also attempted to enforce Environmental Justice policies and pollution or land use bans. In 2014, Chicago passed an ordinance, titled "The Coke and Coal Bulk Material Uses Ordinance", which prohibits the development of petroleum coke and coal facilities in the City of Chicago. In 2016, Portland amended the Fossil Fuel Terminal Zoning to prohibit new Bulk Fossil Fuel Terminals in all zones within the City of Portland. Seattle, Baltimore, and Oakland all have similar bans on coal and fossil fuel facilities. In 2000, San Francisco created the SF EJ program, which awards grants to local community entities to address health inequalities, air quality, and renewable energy. In 2010, Fulton County, GA created an EJ initiative to include community education, policy development, and partnership development. The Georgia EJ initiative resulted in the establishment of policies that require the consideration of the health impact on minority and low-income populations in the decision-making process for land use planning and zoning decisions (Baptista et al, 2019).

While there is movement on all levels of the government to protect the environment and vulnerable communities, the Trump administration threatens progress. They have attempted to roll back 98 environmental protection laws that protect air, water, and land to benefit big industry. Below is a table illustrating the air pollution and emissions rollbacks and their potential effects on the public (Cutler & Dominici, 2018).

Table 1

Air Pollution Rollbacks and Projected Effects

Actions	Projected Effects
Repeal of Clean Power Plan : Reduce carbon dioxide emissions emitted by power generators	• Increased exposure to small particulate matter • An estimated 36,000 deaths over a decade • An estimated 630.000 cases of respiratory ailments in children over a decade.
Rollback of CAFE Standards for Automobiles : Sets fuel consumption standards for cars, trucks, heavy duty trucks, and engines.	• Increases exposure to small particulate matter • An estimated 5,500 deaths over a decade • An estimated 140,000 cases of respiratory ailments in children over a decade
Repeal of emission requirements for glider vehicles.	• Would allow non compliant diesel trucks on the roads. • An estimated 41,000 premature deaths over a decade • An estimated 900,000 cases of respiratory ailments over a decade
Loosening of other air pollution rules involving power plants and solar power tariffs.	• There is a potential for industrial plants to increase emissions by 4 times • Endangers those living near power plants, areas that are high in poverty.

Note. The information provided in Table 1 comes from Cutler & Dominici, 2018.

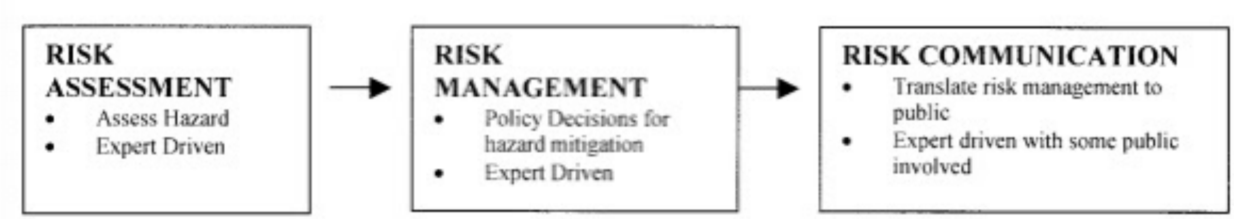
There is also very limited federal research regarding air pollution, illness, and environmental justice at the community level, making it difficult for policies to be backed by evidence. The whole picture is not being painted for federal leaders, and in turn, the most vulnerable communities are being disproportionately impacted. Studies have shown that the

United States has a substantial number of counties that are not being monitored and lack data (Miranda et al, 2011). One reason for this lack of research and initiatives is a lack of funding. From 2010 to 2016, the EPA's budget had been reduced by 21% and positions were reduced by eleven percent. Because of these reductions, programmatic budgets were reduced. More specifically, air quality initiatives that focus on community level air toxins have not received sufficient funding. There is an abundance of knowledge on air toxins nationwide that are listed under the Clean Air Act, but very little is known about community level air toxins exposure. There is also very little known about air pollutants that are outside of the scope of the Clean Air Act (APHA, 2017).

Additionally, studies about population exposure to air pollution typically rely on census data, meaning the effects of air pollution would only be dependent on a person's home address. These studies don't take into account population dynamics and the way in which people move about in their communities during the day. This includes where people work, where they exercise, or where they shop (Universidad Politécnica de Madrid, 2019). Most monitoring systems do provide a general sense of a city's air quality, but hyperlocal data is not available. Local leaders and state officials lack the localized data they need to properly protect the health of their citizens and to reduce emissions in overburdened communities.

Recommendations

Attempts to reduce health disparities and the disease burden of chronic illness and pandemics are core functions within public health. Also consistent with core public health principles are prevention measures that aim to reduce exposure to air pollution that increases the risk of death from chronic disease and pandemics that cause respiratory illnesses. Community support is a key factor in achieving positive public health outcomes, and equitable public health outcomes must address direct threats to human health as well as the social determinants of health. To begin, clear data is needed to inform better policies. Currently, environmental decision making is mostly driven by risk assessment. This means hazards and risk factors are evaluated in order to predict health risks and outcomes, and ultimately inform policy. Risk assessment is criticized for two reasons. First, nearly all assessments emphasize the risk of one type of pollution, typically carcinogens. While environmental justice communities are faced with the issue of carcinogens, they also face multiple other hazards at the same time. Risk assessments normally focus on cancer because it is seen as a proxy for all other health risks posed by pollutants. However respiratory illnesses, neurologic disorders, and immune system dysfunction are often overlooked in risk assessments. Additionally, the pollution faced by EJ communities is often unique to them in that they face it at much larger levels than the rest of their American counterparts. Secondly, local knowledge and expertise is not often accounted for in such assessments. The typical risk assessment follows these three stages; (Corburn, 2002).



As you can see, public engagement in this model is very limited. Lois Gibbs, an American environmental activist, believes that “the people being asked to bear the risk have little chance to escape it, so are forced into discussion of appropriate risk with experts whose values and judgements have determined the terms of the debate (Corburn, 2002).” By ignoring the highly susceptible populations and excluding them in the assessment and research process, this further exacerbates the inequalities that are being done to them. In order to achieve sustainable public health outcomes, community support is needed and necessary. Risk assessments lack community engagement, leaving room for improvement and gaps in success.

One way to bring local knowledge into the assessment process while also considering all cumulative hazards is to conduct community - based cumulative exposure assessments. The first cumulative exposure study done by the EPA was in Williamsburg, New York, and it examined the amount of toxic contamination residents were exposed to through the air, food and water. The first task consisted of creating a module to be applied at the local level. The second task consisted of analyzing the data locally with community members and scientific staff. Through this process, the EPA was able to better understand how to structure the process and model policies moving forward based on the community's concerns (Corburn, 2002). They also gained valuable information from the community members that they would not have gained otherwise. For example, a community group brought to their attention that they should include exposure to perchloroethylene during the assessment process because hundreds of residents lived and worked near dry cleaning facilities. They also learned that many minority residents were eating fish out of a contaminated river, leaving that population exposed to high toxicity (Corburn, 2002).

Since the Williamsburg study, cumulative assessments have become more popular in environmental health. Community-based cumulative risk assessments combine principles of cumulative exposure assessments with community-based profiles. Within environmental health, profiles can refer to different pollutant types, pollution sources, and exposure patterns for individuals within a given community. They can apply real time, real world exposure assessments for all communities (Barzyk, 2010). In order for a community - based cumulative assessment to be successful, there are a few features that have been shown to be successful. First, there should be a listing of all environmental concerns that are issues to the communities.

Second, there should be databases with such environmental information that is publicly available, and there should be modules to include human exposure to multiple different stressors or pollutants. Web-based tools that map this information should include guidance documents of education material on how to best utilize it (Barzyk, 2010).

mHealth Application

Nationwide there are about 4 billion smartphone users, and that number is projected to double by 2022. In the United States, about 80% of smartphone users have downloaded a mobile app in their lifetime, 30% of them being a mobile health app (Larkin, 2017). The creation and use of mHealth apps to improve health are on the rise. There are apps that track wellness goals such as weight loss, smoking, and chronic conditions (Vaghefi, 2019), and apps that track environmental issues such as air quality and symptom surveillance (Johnston, 2018). Mobile technology is available to revolutionize the way air pollution exposure research is done, and when designed well, long term engagement is possible. It opens new opportunities to collect large amounts of passively collected data, which allow for the analysis of population dynamics and pollution exposure.

In conjunction with technology already being used by the EPA and state governments, an mHealth app would allow individuals to monitor their exposures in real time while also acting as an education tool. Within the communities that are greatly affected by air pollution, this mHealth app would give them the tools to become more resilient in their fight for cleaner air. It would allow local and state governments access to real time data in their communities to better inform policies and regulations. On a large scale, the mHealth app has the potential to increase health outcomes for communities currently being overlooked. This mobile app can create a more complete picture of environmental justice by focusing on individual factors that represent the cumulative impacts experienced within different communities. For example, analyzing air pollution, chronic illness, or poverty data alone may tell different stories. However, when you combine all of the factors, they become interrelated. This app has the potential to make this community data accessible for all, understandable, and actionable.

Best Practices. While this mobile data app has the potential to change the way air pollution research is done, individual and community engagement is necessary. The first thing to look at when creating this mobile health app is to make sure it is user friendly. Historically, users stop using mobile health apps after a few times due to user interface, inoperability, inconvenience, and poor navigation (Vaghefi, 2019). The interface should be clean and as simple as possible with little to no advertisements. There should be a navigation menu that is clear, obvious, and easy to function. There should also be navigation instructions and training so users can better understand the functions of the app. Notifications and reminders make it easy for users to utilize the app in a way that it is intended. Alerting users on their phone and guiding them to open the app is more convenient than having to browse the internet for information they should be aware of. Additionally, the app should be so convenient that users really only need to enter in their personal information, as needed. All necessary technology, including location services, mapping and overlays, and health statistic software should be standard and included in the application. Users should be able to customize the app to their needs and to include only information they may be interested in. However, there should not be a lack of available data or resources (Vaghefi, 2019). Additional links or a menu profile should be dedicated to educating users on the impacts the environment has on their health, what pollution is, and what they can do to create better health outcomes. Additionally, when testing the usability of the design and the app, it is crucial to incorporate these vulnerable communities. Digital literacy will play a huge factor in the success of the app among these populations, and continued efforts to engage them and evaluate their understanding is key (Nouri et al, 2019).

Design. In order to increase community engagement and usability, the design of the app needs to be clear, understandable, and familiar. Upon first glance, the interface for the app would look similar to the google maps app used by smartphone users. When the user opens the app, they can see their location on the map and what surrounds them. On Google maps, things like street names, highways, gas stations, and grocery stores pop up in your area. On the mHealth app, the user would still be able to see their location on the map, but there would be more resources available for them to see their surrounding built environment and other health information. This would include mapping overlays like environmental hazards and their location, air quality, allergen levels, disease or illness outbreaks, local hospital and pharmacy wait times, and open clinics and grocery stores. Users would be able to customize the overlays they want visible, while hiding ones they don’t. The navigation menu icon would be on the top left corner of the screen as that is a familiar place for many other apps. Within the navigation menu is where users would be able to sift through available map overlays, personal settings, and general app settings. Users should also be able to choose from multiple different languages, depending on their fluency. Many of the functions within this app already exist individually on the Internet, whether it be through Google, or the EPA, or private air quality index sites. However, none of these things exist simultaneously in such a convenient way. By putting all of these features together in one easy mobile application, users would be able to find the information they needed, when they needed it. They would also be able to look into information they didn’t know about before, acting as an educational tool.

Geographic Information System. Geographic Information System (GIS) mapping and other geospatial tools have and can be utilized to overlay many different environmental factors within a mobile health application. The use of GIS can shine a light on health disparities, resource availability and other health related factors that play a role in how the built environment may affect an individual. The first instance of health GIS was in the 1980's when it was used to determine whether Leukemia clusters were related to nuclear facilities (Musa et al, 2013). GIS is also used in epidemiology for disease surveillance and to monitor public health interventions. GIS has been used to monitor and control onchocerciasis in Guatemala, trypanosomiasis in Africa, and malaria in Israel and Mexico (Musa et al, 2013).

When looking at environmental health and air pollution, GIS maps can include overlays displaying environmental hazards such as superfund sites, chemical plants, highly trafficked roadways, airports, railroads, and other polluting sites. The location of these sites are known and tracked by the EPA, and the data listed would be real time data. Additional overlays should include air quality index maps that illuminate both indoor and outdoor air quality in the user's location in real time. The EPA and other organizations utilize air quality sensors currently to measure pollution in the air, and other mobile apps are already utilizing this data to educate their app users on the air quality index in their area. The app would utilize information from these sensors in the same way. As mentioned previously, there should be overlays for emergency room wait times, hospital wait times, pharmacy openings and wait times, open clinics and potential services, and open grocery stores. During more critical times, such as a pandemic, there could be an overlay that includes businesses selling personal protective equipment in the area, testing locations, and outbreaks in your area. In heavily impacted cities, this information could critically improve outcomes and save lives.

On an individual level, the app would encourage users to include personal information such as gender, race, ethnicity, city and zip code, and age. Ideally, there would be an option to identify illnesses and diseases in which users could track symptoms as they relate to air pollution. These conditions would include but not be limited to asthma, COPD, hypertension, and cardiac disease. As individuals became diagnosed with illnesses, they could track their symptoms in the app, and during pandemics users would be able to identify whether they had been affected by the illness. Individuals would be able to see real time data that is occurring in their neighborhoods or the neighborhoods around them. It would also act as an educational tool for individuals looking for more information about air pollution and how it affects their health. One study of Los Angeles residents found that citizens are aware of air pollution and expressed concerns but were not knowledgeable about the causes of air pollution in their area (Evans, 2005). Behaviors to reduce exposure to air pollution are rare, and sometimes out of an individual's control. However, the biggest indicator of compliance is personal beliefs and knowledge about pollution's negative effects (Evans, 2005). This app would create a tool for users to learn about air pollution, how it is affecting them and their community, and what they can do about it.

At the local or state government level data from the mHealth app, in conjunction with other data systems, can be used to analyze statistics within vulnerable communities. An example of this type of data use is in Kenya. The Division of National AIDS and STI Control Program created a central data repository using a standardized data format to be able to transfer client level HIV data from medical records, laboratories, and mHealth apps into a single data warehouse (Nzyoka et al, 2020). Current public health programs in the United States are underfunded and lack modern information infrastructure. There is also not a lot of sharing information between medical systems.

A robust system is needed to gather and analyze information to better inform policies, and this will include a unified model of public and private partnership. Mobile phone hardware and software development companies could be encouraged to add the mHealth app as a standard component that comes installed on their mobile phones. Telecommunication companies could also be encouraged to offer such mHealth options with their data plans. Additionally, operating system updates pushed out by the mobile phone companies could come with optional mHealth apps for those who elect to download them. Hospitals and local governments could work in conjunction with these providers to access the mHealth data and have a more complete set of statistics to analyze for future research and legislation. These partnerships could create a new landscape for air pollution data collection. mHealth apps allow for the collection of time-activity patterns on potentially hundreds of thousands of individuals for long periods of time. The mHealth app would provide user location information that would allow researchers to build patterns of mobility and to estimate the population distribution patterns of members within communities. Researchers could then cross this data with pollution concentration data to better understand how these patterns of movement within communities truly affect human health at the community level. By understanding air pollution exposure and health implications at the community level, future air pollution regulations will target the sources associated with risk while also addressing environmental justice concerns at a local level.

Funding

Community level air pollution initiative funding at the federal level is limited to an EPA $10 million grant program for state and local agencies (APHA, 2017). The Office of Minority

Health (OMH) also has grant programs that award money to organizations aiming to reduce health disparities and improve minority health. During the COVID pandemic, the OMH created a $20 million grant to develop a national infrastructure to mitigate the effects of the illness within racial and minority communities. Each year, new funding awards are opened up for new applicants to apply (U.S Dept of Health and Human Services, 2020). While the finances would more than likely come from the public sector, partnerships with the private sector need to be made for development and maintenance. Organizations with expertise in mHealth app development would need to be included, as well as experts in the field of air pollution, GIS, and public health.

Implications

Health Impacts

Similar mHealth apps have had positive impacts on health for its users. One example was the Asthma Mobile Health Study (AMHS) which was created to examine asthma triggers, including local air pollution concentrations, and treatment. The AMHS app was downloaded nearly 50,000 times in the 6 months after its launch. The study was able to demonstrate the utility of an mHealth app and successfully link asthma symptoms to changes in heat, pollen and air pollution (Larkin, 2018). In a systematic review, it was also found that the use of mHealth apps have a positive impact on health-related behaviors and clinical health outcomes. App users were more satisfied with using the application to manage their health in comparison to users of conventional care (Han & Lee, 2018). If users of the app become more educated on the environmental justice issues in their community and can internalize the risks, they may start making changes to their daily lives to decrease their risk of exposure. Research supports the use of mHealth apps to improve outcomes in other areas of health such as maternal and infant mortality, treatment adherence, immunization rates, and prevention of communicable diseases (Kruse et al, 2019).

Resource Distribution

Additionally, with better data comes better knowledge of how resources should be accessed and distributed. During a pandemic or other disease outbreak, resource management tools can generate projections based on infection counts and current patient admissions to estimate the number of patients that will require hospitalization, intensive care unit beds, medications, and other health care services. These projections can improve clinical response times and inform triage care strategies, and ultimately save lives.

Impacts for Next Steps

In addition to analyzing the mHealth data and other systems for disease and health outcomes, the data should be analyzed to better inform land use policies. Connections could be drawn and further analyzed from locations of users, pollution proximity, and disease outcomes. Because GIS highlights only associations, any results from GIS analyses and mapping require further research and studies to identify causal relationships between any of the overlaid variables. From here, metric boundaries around highly polluted land could be put in place to reduce exposure to vulnerable communities that would typically live in these areas. Stricter land use rules should also be considered when building new construction. When adequate housing protects individuals and families from harmful exposures, it can make important contributions to health. Taking these populations away from polluted areas may decrease their prevalence of asthma and other chronic conditions that make them more susceptible to respiratory pandemics.

Limitations

One major limitation with mobile health applications is user adherence. Users often stop usage of mHealth apps very quickly after initial use. This can be for many reasons including poor app quality, hard to operate interfaces, and disinterest over time. Another limitation is data privacy concerns. Users may be hesitant to input information into the app for a fear of privacy breach. Additionally, users may misinterpret information on the application or may have difficulty understanding and navigating the app. There are also limitations to using GIS for data analysis purposes. Any analyses employed by GIS software simply highlights associations and does not give you causal relationships. Resource limitations are a constant problem in all GIS-related research, so researchers are often restricted by the data that is available to them. However, this further highlights the need for better data collection in regard to disease and the built environment.

Conclusion

COVID-19 has reinforced the need for policies guided by evidence that ensures the safety and health of both humans and the planet. It has brought longtime inequities into focus and has shed a light on the disparities faced by communities of color. A history of segregation and current structural inequalities put these communities at a heightened risk for illness and disease. Current public health infrastructure does not capture the necessary data to make the much-needed changes within these overburdened communities. The use of an mHealth application could help bridge this data gap while simultaneously acting as a resource for individuals within the communities and local leaders and state officials. Policymakers tasked with rebuilding healthier and more resilient communities in a post-pandemic world can use this localized data to work more effectively with residents and stakeholders to implement powerful interventions that reduce air pollution in these vulnerable communities.

References

American Public Health Association (APHA). (2017). Public Health Opportunities to Address the Health Effects of Air Pollution. https://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2018/01/18/public-health-opportunities-to-address-the-health-effects-of-air-pollution

Baptista, A.I., Sachs, A., & Rot, C. (2019). Local Policies for Environmental Justice: A National Scan. Tishman Environment and Design Center. https://www.nrdc.org/sites/default/files/local-policies-environmental-justice-national-scan-tishman-201902.pdf

Barzyk, T., Conlon, K., Chahine, T. et al. (2010). Tools available to communities for conducting cumulative exposure and risk assessments. *J Expo Sci Environ Epidemiol* 20, 371–384. https://doi.org/10.1038/jes.2009.25

Bell, M. L., & Ebisu, K. (2012). Environmental inequality in exposures to airborne particulate matter components in the United States. *Environmental health perspectives*, 120(12), 1699–1704. https://doi.org/10.1289/ehp.1205201

Bergman, M. (2019). They chose us because we were rural and poor': when environmental racism and climate change collide. *The Guardian.* https://www.theguardian.com/environment/2019/mar/08/climate-changed-racism-environment-south.

Berkovitz, C. (2020). Environmental Racism Has Left Black Communities Especially

Vulnerable

to COVID-19. *The Century Foundation.* *https://tcf.org/content/commentary/environmental-racism-left-black-communities-especially-vulnerable-covid-19/?session=1*

Bui, E. (2019). Cities Start to Question an American Ideal: A House With a Yard on Every Lot. *The New York Times. https://www.nytimes.com/interactive/2019/06/18/upshot/cities-across-america-question-single-family-zoning.html*

Centers for Disease Control and Prevention. (2019). Health, United States Spotlight; Racial and Ethinic Disparities in Heart Disease. https://www.cdc.gov/nchs/hus/spotlight/HeartDiseaseSpotlight_2019_0404.pdf

Centers for Disease Control and Prevention. (2020). People with Certain Medical Conditions. https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-with-medical-conditions.html

Clay, K., Lewis, J., & Severnini, E. (2018). Pollution, Infectious Disease, and Mortality: Evidence from the 1918 Spanish Influenza Pandemic. *The Journal of Economic History*, 78(4), 1179-1209. doi:10.1017/S002205071800058X

Corburn, J. (2002). Environmental Justice, Local Knowledge, and Risk: The Discourse of a Community - Based Cumulative Exposure Assessment. DOI: 10.1007/s00267-001-0013-3

Covidtracking.com. (2020). Racial Data Dashboard. https://covidtracking.com/race/dashboard.

Cutler D, Dominici F. (2018) A Breath of Bad Air: Cost of the Trump Environmental Agenda May Lead to 80 000 Extra Deaths per Decade. *JAMA,* .319(22):2261–2262. doi:10.1001/jama.2018.7351

Eligon, J. (2016). A Question of Environmental Racism in Flint. *The New York Times.*

https://www.nytimes.com/2016/01/22/us/a-question-of-environmental-racism-in-flint.html.

EPA.gov. (n.d). Our Mission and What We Do. https://www.epa.gov/aboutepa/our-mission-and-what-we-do

Epa.gov. (2020) What is a Superfund? *United States Environmental Protection Agency.* https://www.epa.gov/superfund/what-superfund.

Evans, G., Colome, S., & Shearer, D. (2005). Psychological reactions to air pollution. *Environmental Research*, 45, 1-15. https://doi.org/10.1016/S0013-9351(88)80002-1

Fleischman, L. & Franklin, M. Fumes (2017). Across the Fence-Line: The Health Impacts of Air Pollution from Oil & Gas Facilities on African American Communities. https://live-naacp-site.pantheonsite.io/wp-content/uploads/2017/11/Fumes-Across-the-Fence-Line_NAACP-and-CATF-Study.pdf

Gately, C. & Reardon, T. (2020). Racial Disparities in the Proximity to Vehicle Air Pollution in the MAPC Region. *Metropolitan Area Planning Council.* https://www.mapc.org/pollution-disparities-covid19/

Gould, E. & Wilson V. (2020). Black workers face two of the most lethal preexisting conditions for coronavirus—racism and economic inequality. Economic Policy Institute. https://files.epi.org/pdf/193246.pdf

Gray, W., Shadbegian, R., & Wolverton, A. (2010). Environmental Justice: Do Poor and Minority Populations Face More Hazards? *National Center for Environmental Economics.* https://www.epa.gov/sites/production/files/2014-12/documents/environmental_justice_do_poor_and_minority_populations_face_more_hazards.pdf

Han, M., & Lee, E. (2018). Effectiveness of Mobile Health Application Use to Improve Health Behavior Changes: A Systematic Review of Randomized Controlled Trials. Healthcare informatics research, 24(3), 207–226. https://doi.org/10.4258/hir.2018.24.3.207

Hutchins, S. S., Fiscella, K., Levine, R. S., Ompad, D. C., & McDonald, M. (2009). Protection of racial/ethnic minority populations during an influenza pandemic. *American journal of public health*, *99 Suppl 2*(Suppl 2), S261–S270. https://doi.org/10.2105/AJPH.2009.161505

Johnston, F., Wheeler, A., Williamson, G., Campbell, S., Jones, P., Koolhof, I., & et al. (2018). Using smartphone technology to reduce health impacts from atmospheric environmental hazards. *Environmental Research Letters.* 13. 10.1088/1748-9326/aab1e6.

Karlson, K. (2020). Cancer Alley now Coronavirus Alley; The pollution-induced illnesses these Louisianans have suffered for decades put them at greater risk from COVID-19. *The Sierra Club.* https://www.sierraclub.org/sierra/cancer-alley-now-coronavirus-alley.

Kolak, M., Bhatt, J., Park, Y. H., Padrón, N. A., & Molefe, A. (2020). Quantification of Neighborhood-Level Social Determinants of Health in the Continental United States. *JAMA network open*, *3*(1), e1919928. https://doi.org/10.1001/jamanetworkopen.2019.19928

Kruse, C., Betancourt, J., Ortiz, S., Valdes Luna, S. M., Bamrah, I. K., & Segovia, N. (2019). Barriers to the Use of Mobile Health in Improving Health Outcomes in Developing Countries: Systematic Review. *Journal of medical Internet research,* 21(10), e13263. https://doi.org/10.2196/13263

Landrigan, P.J., Fuller, R.,Acosta, N.J.R.,Adeyi, O.,Arnold, R.,Basu, N.,Balde, A.B., et al.

(2018). The Lancet Commission on pollution and health. The Lancet 391(10119):462–512.

Larkin, A., & Hystad, P. (2017). Towards Personal Exposures: How Technology Is Changing Air

Pollution and Health Research. *Current environmental health reports,* 4(4), 463–471. https://doi.org/10.1007/s40572-017-0163-y

Lawton, B. (2020). Protect and Improve Air Quality to Prevent High Mortality Rates from Future Pandemics. The Network for Public Health Law: Environment, Climate, and Health. https://www.networkforphl.org/news-insights/protect-and-improve-air-quality-to-prevent-high-mortality-rates-from-future-pandemics/

Lee, J. J., Bankhead, C., Smith, M., Kousoulis, A. A., Butler, C. C., & Wang, K. (2018). Risk factors for influenza-related complications in children during the 2009/10 pandemic: a UK primary care cohort study using linked routinely collected data. *Epidemiology and Infection*, 146(7), 817–823. https://doi.org/10.1017/S0950268818000353

Miranda, M. L., Edwards, S. E., Keating, M. H., & Paul, C. J. (2011). Making the environmental justice grade: the relative burden of air pollution exposure in the United States. *International journal of environmental research and public health*, 8(6), 1755–1771. https://doi.org/10.3390/ijerph8061755

Morales, K. F., Paget, J., & Spreeuwenberg, P. (2017). Possible explanations for why some countries were harder hit by the pandemic influenza virus in 2009 - a global mortality impact modeling study. BMC infectious diseases, 17(1), 642. https://doi.org/10.1186/s12879-017-2730-0

Musa, G. J., Chiang, P. H., Sylk, T., Bavley, R., Keating, W., Lakew, B., Tsou, H. C., & Hoven,

C. W. (2013). Use of GIS Mapping as a Public Health Tool-From Cholera to Cancer. *Health services insights*, 6, 111–116. https://doi.org/10.4137/HSI.S10471

Nardone, A., Casey, J. A., Morello-Frosch, R., Mujahid, M., Balmes, J. R., & Thakur, N. (2020). Associations between historical residential redlining and current age-adjusted rates of emergency department visits due to asthma across eight cities in California: an ecological study. *The Lancet. Planetary health*, 4(1), e24–e31. https://doi.org/10.1016/S2542-5196(19)30241-4

National Cancer Institute. (2019). Cancer Disparities. https://www.cancer.gov/about-cancer/understanding/disparities#:~:text=Some%20key%20cancer%20incidence%20and,to%20die%20of%20breast%20cancer.

National Park Service. (2018). Where Does Air Pollution Come From? https://www.nps.gov/subjects/air/sources.htm

The New York Times. (2020). New York City Coronavirus Map and Case Count. https://www.nytimes.com/interactive/2020/nyregion/new-york-city-coronavirus-cases.html

NMHC. (2019). Source of Income Laws By State, County and City. National Multifamily Housing Council. https://www.nmhc.org/research-insight/analysis-and-guidance/source-of-income-laws-by-state-county-and-city/

Nouri, S. S., Avila-Garcia, P., Cemballi, A. G., Sarkar, U., Aguilera, A., & Lyles, C. R. (2019). Assessing Mobile Phone Digital Literacy and Engagement in User-Centered Design in a Diverse, Safety-Net Population: Mixed Methods Study. JMIR mHealth and uHealth, 7(8), e14250. https://doi.org/10.2196/14250

Nzyoka, R. & Dwivedi, V. (2020) Real-time Data Could Save more People from COVID-19. New Security Beat; the blog of the Environmental Change and Security Program. https://www.newsecuritybeat.org/2020/04/real-time-data-save-people-covid-19/

Office of the Attorney General, State of CA Department of Justice. SB 1000 - Environmental Justice in Local Land Use Planning. https://oag.ca.gov/environment/sb1000#:~:text=In%20an%20effort%20to%20address,environmental%20justice%20communities%20

Orellano, P., Quaranta, N., Reynoso, J., Balbi, B., and Vasquez, J. (2017). Effect of outdoor air pollution on asthma exacerbations in children and adults: Systematic review and multilevel meta-analysis. PLoS ONE 12(3):e0174050. https://doi.org/10.1371/journal.pone.0174050

Pope, C. A., 3rd, & Dockery, D. W. (2006). Health effects of fine particulate air pollution: lines that connect. Journal of the Air & Waste Management Association (1995), 56(6), 709–742. https://doi.org/10.1080/10473289.2006.10464485.

Rosofsky. A., Levy, J. I., Zanobetti, A., Janulewicz, P., & Fabian, P. (2017). Temporal trends in air pollution exposure inequality in Massachusetts. *Environmental Research, 161, 76-86.* https://doi.org/10.1016/j.envres.2017.10.028

Rothstein, R. (2017).The Color of Law: A Forgotten History of How Our Government Segregated America. New York: Liveright Publishing.

Skelton, R. & Miller, V. (2016). The Environmental Justice Movement. *National Resources Defense Council.* https://www.nrdc.org/stories/environmental-justice-movement.

Tessum, C.W., Apte, J. S., Goodkind, A. L., Muller, N. Z., Mullins, K. A., David A. Paolella, D.

A., et al. (2019). Inequity in consumption of goods and services adds to racial–ethnic disparities in air pollution exposure. *National Academy of Sciences*, 116 (13) 6001-6006; DOI: 10.1073/pnas.1818859116

Union of Concerned Scientists. (2019). Inequitable Exposure to Air Pollution from Vehicles in California: Fact Sheet. https://www.ucsusa.org/sites/default/files/attach/2019/02/cv-air-pollution-CA-web.pdf

Union of Concerned Scientists. (2019). Inequitable Exposure to Air Pollution from Vehicles in the Northeast and Mid-Atlantic. https://www.ucsusa.org/resources/inequitable-exposure-air-pollution-vehicles

United States Environmental Protection Agency. (2019). Summary of the National Environmental Policy Act. https://www.epa.gov/laws-regulations/summary-national-environmental-policy-act

United States Environmental Protection Agency. (2020). Overview of the Clean Air Act and Air Pollution. https://www.epa.gov/clean-air-act-overview

Universidad Politécnica de Madrid. (2019). Using mobile phone data to estimate air pollution exposure. https://phys.org/news/2019-07-mobile-air-pollution-exposure.html

U.S Department of Health and Human Services, Office of Minority Health. (2019) Minority Population Profiles: Black/African Americans. https://minorityhealth.hhs.gov/omh/browse.aspx?lvl=3&lvlid=61

U.S Department of Health and Human Services, Office of Minority Health. (2020). FY 2020 Funding Opportunity Announcement. https://minorityhealth.hhs.gov/omh/browse.aspx?lvl=2&lvlid=97

US GAO. (GAO 1995). Superfund: Information on Current Health Risks. GAO Report Number

GAO/RCED-95-205. https://www.gpo.gov/fdsys/pkg/GAOREPORTS-RCED-95-205/html/GAOREPORTS-RCED-95-205.htm.

Vaghefi, I., & Tulu, B. (2019). The Continued Use of Mobile Health Apps: Insights From a Longitudinal Study. *JMIR mHealth and uHealth*, 7(8), e12983. https://doi.org/10.2196/12983

World Health Organization. (n.d.). Ambient air pollution: Health impacts. https://www.who.int/airpollution/ambient/health-impacts/en/

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* 2020.04.05.20054502; doi: https://doi.org/10.1101/2020.04.05.20054502

Zeger S. L., Dominici F., McDermott A., & Samet J. (2008)Mortality in the Medicare population and chronic exposure to fine particulate air pollution in urban centers (2000-2005). *Environ Health Perspect*. (116), 1614-1619.

Appendices

USF Competency Matrix

UNIVERSITY OF SAN FRANCISCO | School of Nursing and Health Professions

MPH Competencies Checklist for Fieldwork

Note: All students must identify which competencies they will be addressing in their practicum. The student must demonstrate having obtained a minimum of **FIVE** competencies through the Fieldwork experience, **THREE** of which must be Foundational.

CEPH Foundational Competencies

Competency	Description of how used for Capstone
Evidence-based Approaches to Public Health	
1. Apply epidemiological methods to the breadth of settings and situations in public health practice	Analyzed and synthesized epidemiological data across multiple studies and developed a literature matrix to summarize key components of findings.
4. Interpret results of data analysis for public health research, policy and practice	Used data from the literature to inform recommendations for public health practice.
Public Health & Health Care Systems	

5. Compare the organization, structure, and function of health care, public health, and regulatory systems across national and international settings	Analyzed system level factors affecting black communities during pandemics and made recommendations based on the specific gaps after a comprehensive review of the literature.
6. Discuss the means by which structural bias, social inequities and racism undermine health and create challenges to achieving health equity at organizational, community and societal levels	Discussed the ways in which racial segregation, access to healthcare, housing, and zoning have led to negative health outcomes for communities of color and low-income populations
Planning & Management to Promote Health	
9. Design a population-based policy, program, project or intervention	Laid out a framework for developing a mHealth application.
Policy in Public Health	
12. Discuss multiple dimensions of the policy-making process, including the roles of ethics and evidence	Provided evidence from different levels of the socio ecological model to show how communities of color are affected by disease and illness.
14. Advocate for political, social and economic policies and programs that will improve health in diverse populations	Advocating for increased data collection to improve health outcomes within vulnerable communities
Communication	

19. Communicate audience-appropriate public health content, both in writing and through oral presentation	Outlined, drafted and finalized Capstone paper including a literature review, recommendations and implications on a current public health problem. Created a slide deck based on the Capstone paper and delivered an oral presentation at Health Professions Day in front of an interprofessional audience.