Breathless in the Motor City: Unveiling the Legacy, Challenges, and Mitigation Strategies of Air Pollution in Detroit

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This paper delves into the historical trajectory, current status, and consequential ramifications of air pollution in the city of Detroit. With a specific emphasis on the pollutants NO2, SO2, PM2.5, and O3, the study scrutinizes the health implications and societal burdens arising from the escalating air pollution levels against the backdrop of Detroit's historical evolution. Despite regulatory endeavors, Detroit's enduring role as an industrial and manufacturing hub substantiates the escalating health and economic toll of air pollution. These costs disproportionately impact vulnerable demographics, including the elderly, children, and individuals with chronic illnesses. The paper underscores racial disparities in the distribution of this burden.

To address these challenges, the paper advocates for a mitigation strategy inspired by the European Union's NEC Directive. The proposed approach involves intensified monitoring of pollutants, implementation of targeted policies, and enhanced industrial regulations. Ultimately, this paper comprehensively examines the historical legacy, contemporary, and future dimensions of air pollution in Detroit, delineating the profound impact on the city and its residents, while offering strategic recommendations for mitigation.

Keywords

Air Pollution • Detroit • Health Implications • Racial Disparities • Mitigation Strategies • Environmental Impact

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Legacy of the Issue and Introduction

An investigation into the air quality of Detroit today requires introspection into the past. Detroit's history is inexorably linked to that of the automotive industry and manufacturing. Emerging in the post-World War two boom as the center of American automotive manufacturing Detroit blossomed into an economic and industrial American powerhouse ("Environmental Justice in Detroit," n.d.). The city quickly grew and expanded around the all-encompassing automobile, and large plants were created within the city while urban development centered around personal car ownership and highways, moving away from a more traditionalist close-knit walkable urban design. This large growth occurred in the early half of the 20th century; an era marked by a laissez-faire attitude towards environmental protections. Shortsighted environmental policy ensured lax standards on emissions from the burgeoning automotive plants, while poor urban planning prioritized a drivable spaced-out city over a traditionalist city that relied on low-emission public transport ("Environmental Justice in Detroit," n.d.). This boom would come to a sudden and abrupt crash, as racial tensions, and financial downturn within the automotive industry, destroyed the city's economy and the exodus of upper- and middle-class residents eroded property values within the city. The result was a poorly planned city that had short-sighted environmental policy and emitted industrial waste into the air unperturbed for nearly a half decade ("Environmental Justice in Detroit," n.d.). However, growing public concerns about the effects of air pollution led to the state passing Act 348 in 1965, establishing the state's first air pollution control law ("Air Quality Politics in Michigan," n.d.). The act proved to be ineffective at stopping the rates of air pollutants in the city of Detroit, as citizens continued to be negatively affected by industrial air pollution. The passing of the Clean Air Act in 1970 by the EPA, however, brought greater regulation on Detroit's air pollution setting emission standards, and a baseline fine of $10,000 for emitters (Stern, 1982). Sadly, Detroit and Michigan as a whole struggled to comply with EPA standards, even as far as 1972, ("Air Quality Politics in Michigan," n.d.). The EPA eventually intervened, imposing its fines and plans on the state to ensure it fell under compliance with the Clean Air Act (Stern, 1982). This move was contested by major industries such as Dow Chemical and Detroit Edison, who cited inaccuracies within EPA testing, and that EPA standards were redundant, setting the stage for opposition between industry and environmental regulation within the city that persists today ("Air Quality Politics in Michigan," n.d.).

Specific Pollutants and Sources

The air of today's Detroit is awash with both organic and synthetic pollutants, due to the lingering manufacturing power of the city, and the city's poor automobile-based design. The first polluter is known as the "point source", a stationary emitter such as a factory smokestack, while the latter is known as a "mobile source", a moving polluter such as a car or a lawnmower (Walding, 2016). The primary actors in the narrative of Detroit's air pollution are NO2, SO2, PM2.5, and O3 (Walding, 2016). NO2 refers to Nitrogen dioxide which is created by point sources but also industrial processes (von Schneidemesser, 2015). SO2 refers to sulfur dioxide, which is created through industrial processes and energy generation, it is mostly a result of point source emitters. PM2.5 refers to particulate matter, mixtures of tiny chemicals, metal compounds, solids, and liquids that persist in the atmosphere. The designation of 2.5 references their respective size in micrometers as they are a result of point and mobile sources, respectively (von Schneidemesser, 2015). Lastly, O3 refers to Ozone, specifically ground-level ozone. Created through industrial processes and car emissions, it is both an emission from point and mobile sources (von Schneidemesser, 2015). Within the city of Detroit, point sources refer to industrialized zones within the city, such as steel plants on Zug Island, or Marathon petroleum refineries (Lougheed, 2014). Mobile sources within the city refer to the multitude of high-traffic highways such as I-75, which cut a swath through the city (Lougheed, 2014). These pollutants constitute the major source of air pollution in Detroit.

Standards

A downward trend in the emission of air particulates has been observed in the city of Detroit across the last 14 years (Walding, 2016). However, while air quality in Detroit remains largely below EPA guidelines it is still a health threat to the thousands of individuals that call Detroit home. Air pollution is not uniformly issued across Detroit as it is often fluctuation due to several factors, including weather conditions, time of day, and season (Martenies et al, 2017). However, using data obtained from Michigan's 2017 Air Emissions Reporting System, Detroit on average experiences NO2 at 23.5 ppb, with a minimum (min) recording of 5.8 ppb, and a maximum recording of 214.2 ppb (Martenies et al, 2017). EPA guidelines set a recommended limit of 53 ppb. (Environmental Protection Agency, 2014), and while the daily average exposure falls within safe guidelines, days can fluctuate to exceed the recommended EPA value by as much as a recorded 4x. Such fluctuations reveal a serious trend in Detroit air pollution. While average exposure values generally fall within the safe EPA regulation, fluctuations can lead to massive exposures and subsequent negative health effects among the exposed. Ozone (O3) experiences an average ppb exposure of 38.3, with a minimum recording of 6.8 ppb and a maximum recording of a Q1 recording of 103.8 ppb, a value exceeding EPA regulation by 1.48x. The EPA regulation is set at 0.07 ppm (70 ppb) (Environmental Protection Agency, 2014). SO2 had an average daily exposure of 1.1 ppb with a minimum recording of 0.0 ppb and a maximum recording of 19.4 ppb (Martenies et al, 2017). The EPA recommendation is a 75 ppb SO2 exposure for a 1-hour standard (Environmental Protection Agency, 2014). Lastly, PM2.5 was 10.7 microgram per cubic meter (μg/m^3) with a minimum reading of 2.0 μg/m^3 and a maximum reading of 82.4 μg/m^3, the maximum reading was 2.35x the EPA guidelines of 35 μg/m^3. While the general average exposure to some of these pollutants falls well within acceptable EPA guidelines, the heavy fluctuation of the city's air pollution exposes Detroit residents to periods of 1–4x EPA acceptable guidelines and can lead to negative health outcomes.

Health Effects of Air Pollution

Exposure to air pollution is causally linked to several negative health outcomes. Ecological studies have concluded a causal relationship between air pollution and cardiovascular disease, cancer development, respiratory illness, and stroke (Keswani et al, 2022). Meta-analysis research has even conducted an estimation of dose-response gradients with air pollution. Using such methods, peer-reviewed research has found that a "10 μg/m3 increase in PM2.5 levels was associated with a 2.5% increase in the relative risk of myocardial infarction (MI)" (Keswani et al, 2022). Similarly, "every 10 μg/m3 increase in exposure to PM2.5 was associated with a 22% increased risk of all-cancer mortality in a linear concentration-response relationship." (Keswani et al, 2022). PM2.5 is thus a significant causal factor in both cancer and respiratory illness and has even demonstrated a biological gradient, to both infections. This means the large fluctuations of PM2.5 within the city exacerbate the risk of the disease along a linear trend. Additionally, air pollution has been linked to immunological dysregulation, inflammatory bowel disease, chronic kidney disease, end-stage renal disease, and decline in glomerular filtration rate, higher risk of tuberculosis and COVID-19 infections (Keswani et al, 2022). As these links lack the necessary criteria to prove direct causality (under Bradford Hill's criteria), they cannot prove that increased exposure leads to all the negative health outcomes listed. However, increased and continued research into the field will aim to identify other potential negative health outcomes associated with air pollution exposure. Beyond direct links to disease outcome, air pollution's greatest health effect is that of the syndemic factor. Broadly speaking a syndemic factor is a factor that forms synergistic interactions between multiple health threats which contribute to the excess burden of the disease. In this way, exposure to air pollution enhances the burdens of at-risk populations who already have a disease or medical health risks.

At-Risk Populations

Air pollution in the form of SO2, NO2, O3, and PM 2.5, poses a significantly increased risk for the elderly, children, and people with chronic respiratory illness (such as asthma) (Simoni et al, 2015). For older populations, outdoor air pollution poses an increased threat to their respiratory health. Research has "shown significant positive associations between respiratory hospital admissions and levels of SO_2, PM_{10} , and O_3 in persons aged 65 years or older" (Simoni et al, 2015). The strongest association was that of PM2.5, which is found to be the most threatening for the elderly (Simoni et al, 2015). The exact reasoning for this is still unclear to public health officials, but a meta-analysis of over 33 studies has found that "each 10 μg/m3 increase in PM2.5 was associated with a 0.51% (95% CI, 0.30–0.73%) increase in respiratory mortality" (Simoni et al, 2015). Such research has established a dose-response gradient for elderly populations, proving causal mortality increase due to PM2.5 exposure. Contextually within the city of Detroit, elderly people are at an increased risk of negative health outcomes related to air pollution. Previous studies have calculated relative risks associated with increases in air pollution chemicals. A value over 1 in a relative risk test indicates that the pollutant exposure has caused more disease outcomes than normally expected, and thus exposure to the pollutant increases the likelihood of the disease. PM2.5 and O3 have been shown to be associated with a relative risk of 1.012 and 1.026, respectively, for pneumonia hospitalization in elderly Detroit residents (Schwartz, 1994)." Similarly, the relative risk for COPD (chronic obstructive pulmonary disease) revealed a relative risk of 1.02 for PM2.5 and a relative risk of 1.028 for ozone exposure (Schwartz, 1994). Thus, within the city, the pollutant has statistically increased the burden of the two diseases to a causal level. Such research has concluded that elderly Detroit residents will face increased hospitalization for COPD and Pneumonia than the national average due to air pollution (Schwartz, 1994). Ultimately, contemporary research has concluded that existing levels of ozone and fine particulate matter in the city of Detroit (which fall within EPA regulations) pose a statistically increased risk for elderly residents in the city (Schwartz, 1994).

For children, air pollution poses an increased threat as well, owing to children's increased respiration rate (compared to that of adults), underdeveloped organs, and on average a higher time spent outside than adults (Brumberg et al, 2021). In children exposure to ambient air pollution has been found to ". . . manifest as exacerbations of chronic diseases (eg, asthma) but air pollution also appears to be associated with the development of major pediatric diseases, including adverse birth outcomes, abnormal lung and neurodevelopment, and pediatric cancer, as well as obesity and cardiovascular disease risk." (Brumberg et al, 2021). As such air pollution exposure is statically associated with chronic disease development into adulthood and linked to adverse neural and organ development and cancers (Brumberg et al, 2021). Contextually within Detroit, children are hospitalized for asthma (related to air pollutant exposure), at a tremendous rate, as the childhood asthma hospitalization rate was three times the childhood asthma rate for Michigan children (Detroit: current status of Asthma, 2021). Sadly, public health data on children's development due to Detroit's air pollution is an underdeveloped subject. Potential prospective cohorts following disease development could help to establish a baseline relative risk assessment and shed much-needed light on the situation within the city.

Lastly, individuals with chronic respiratory illness face increased susceptibility to air pollution. Air pollution causes increased inflammation in the respiratory tract, leading to increased hospitalizations and mortality in populations that are burdened by respiratory chronic illness (Brumberg et al, 2021). Within the greater context of Detroit, citizens suffer increased asthma burdens, likely related to ambient air pollution as public health has associated exposure to asthma development (though not causally proven within the city) (Brumberg et al, 2021). The rate of adult Detroiters with asthma was 29% higher compared to the rest of the state (Detroit: Current Status of Asthma, 2021). Public health surveillance as recently as 2021 has found that Detroiters living with asthma face an increased risk of hospitalization compared to the state average. In 2019 alone there were 1,458 hospitalizations from asthma in Detroit, with a hospitalization rate that is 4x the state average ("Environmental Justice in Detroit," n.d.). Similarly, the rate of asthma mortality for Detroit residents was over 3x the state average (Detroit: Current Status of Asthma, 2021). Thus, Detroit's residents with asthma will disproportionately face increased mortality and hospitalizations due to the city's air pollution.

Racial Disparities

Detroit has a long history of racial and ethnic disparities. Redlining, predatory race-based employment, loaning, and racial rioting are the foundation of the city's history (Schulz et al, 2016). Unfortunately, air pollution is no exception; negatives will disproportionately affect African Americans and ethnic minority groups. Contemporary research has concluded that African Americans and ethnic minority groups (such as Latino ethnic populations) disproportionately experience negative health effects associated with air pollution (Schulz et al, 2016). Such populations are more likely to be situated in the city's lowest valued areas and are more likely to be situated at a close distance to point and mobile sources (in this case mobile sources would refer to highway proximity) (Schulz et al, 2016). Quantitatively, public health case studies have concluded that within the city of Detroit "census tracts with greater proportions of people of color (POC) experience a heightened burden of environmental exposures and health risks (–0.12, $p < 0.001$)." (Schulz et al, 2016). For context, the study found that the proportions of POC experienced a statistically significant burden from air pollution using a cumulative risk index, which compares census data of populations with their locations and hazards to determine if such populations experience disproportionate health outcomes (Schulz et al, 2016). Such research concluded that Detroit POC populations face the burden of air pollution to a statistically significant disproportionate effect. Contemporary and historical explanations determine that "these findings are consistent with evidence suggesting that patterns of White flight and economic disinvestment from many urban communities, such as those described above for Detroit, have contributed to the disproportionate representation of African Americans and Latinos in neighborhoods that experience multiple exposures and vulnerabilities" (Schulz et al, 2016). Additionally, another racial disparity responsible for the increased burden on POC is asthma. Detroit faces enhanced asthma rates compared to other Michigan cities and populations. As examined above air pollution leaves those with asthma extremely susceptible to hospitalization and mortality, even when pollution levels fall within EPA standards. However, the brunt of Detroit's asthmatics are disproportionately POC. A 2019 Michigan state-funded ecological study found that "In 2019, the rate of asthma hospitalization among Black persons in Detroit was 31.0 per 10,000. The rate among white persons in Detroit was 7.9 per 10,000" (Detroit: current status of Asthma, 2021). Such data found conclusively the burden of asthma in the city was statistically experienced by African Americans in the city. Public health research links such a chronic burden to the localization of African Americans closer to point and mobile sources. Research has found that long-term exposure to air pollution has a causal linkage to chronic disease development, primarily in asthma (Brumberg et al, 2021)

Costs

The costs of such exposures are tremendous on both the health of Detroit citizens and the city's economy is tremendous. Both in terms of GDP (a measure of economic activity) and DALYs (disability-adjusted life years) a metric determining lost years due to premature mortality and disability relating to disease, and mortality. In Detroit, exposures to O3 PM2.5 so2 and NO2, resulted in an estimated 10,000 DALY yearly, representing over 6.5 billion annually in impacts (Martenies et al, 2017). Air pollutant exposure accounts for 3,300 asthma emergency department visits yearly (Martenies et al, 2017). The breakdown for attributable burden between the pollutants for DALYs found that 97% of 10,000 were related to PM2.5, 1% related to O3, 0.06% related to So2, and 1.3% related to NO2 (Martenies et al, 2017). Monetary costs related to each pollutant varied slightly, with the 6.5 billion health cost broken down, 78% of the burden was due to PM2.5, 21% for O3, 0.03% was due to SO2, and finally, 0.5% was due to NO2 (Martenies et al, 2017). Further, an estimated 5.5% of annual city deaths can be attributed to PM2.5 while 1.5% can be attributed to ozone exposure (Martenies et al, 2017). Research has concluded that both health costs and GDP costs are the most heavily associated with PM2.5 and ozone (Martenies et al, 2017). Unequivocally the costs of air pollution within the city are an immense burden on the citizens residents, medical infrastructure, and economy. Unaddressed, these costs will hamper the city's development and pose a growing public health crisis. An estimated 570,000 school days are missed due to air pollution in the city, due to asthma attacks and hospitalizations (Martenies et al, 2017). Despite falling within acceptable EPA limits, ambient air pollution in the city presents an egregious public health crisis to the city of Detroit, with annual costs that burden and impoverish its citizens and their futures.

Impact on the Environment

Beyond human health impacts, air pollution has a profound and damaging effect on the environment of Detroit. Unfortunately, there is a marked lack of information on the environmental effects of air pollution within the city of Detroit. As such quantitatively defining the environmental impacts that Detroit's air pollution levels incur is nearly impossible. The effects of air pollution on the environment have been studied in other ecological studies but have yet to be compiled on the city of Detroit itself. This is an extreme shortcoming of public health and environmental initiatives, as air pollutants have been found to have a profound effect on environmental ecology. Ozone exposure is a phytotoxin, which can impair plants' photosynthesis and oxidize plant tissues (von Schneidemesser, 2015). Therefore, it has a negative effect on crop yield, specifically in wheat, maize, and soybeans, costing an estimated 11–18 billion dollars worth of damages to the US agricultural economy (von Schneidemesser, 2015). Likewise, SO2 emissions have been found to have an adverse effect on ecosystems through acid deposition. When SO2 meets water and air, it undergoes a chemical change to sulfuric acid, which during precipitation causes deforestation, acidification of waterways, and the mortality of aquatic life (von Schneidemesser, 2015). PM2.5 is responsible for meteorological changes, including precipitations, humidity, and haze (von Schneidemesser, 2015). The shortcoming of public health officials to quantify the damages of Detroit's air pollution on the environment reflects a lack of respect and investment in environmental surveillance and health from the US government. To ensure a healthier Detroit environment, public health systems should quantify these health problems through prospective cohorts, and syndemic surveillance.

Mitigation Strategy and Program Potential

Despite falling within EPA limits, air pollution is a disastrous public health crisis affecting the city of Detroit. Left unaddressed, this pollution will lead to lasting economic and health damage and increasing racial disparity. Thus, mitigation should offer strategic interventions that are specialized for the citizens' unique situation, rather than follow vague national guidelines.

Perhaps the most comprehensive strategy with proven results comes from the European Union. Under the directive "NEC Directive, (2016/2284/EU)", the EU set about reducing levels of SO2, fine particulate matter, NO2, and ozone (European Environment Agency, 2023). Lauded as the most stringent enforcement by the Union, the directive put in place aggressive monitoring of pollutants in European nations, pollutant level targets for EU member countries, and the development of tailor-made air quality control plans for each member nation's unique situations (European Environment Agency, 2023). The beauty of the EU plan was its flexibility and strict implementation of monitoring sites. States were able to create tailor-made plans that maximized cost-effectiveness and benefits for their particular pollution situations. Additionally, accurate monitoring allows states to identify polluters and impose taxes as well as limits on industry. Introspection of the most effective measures implemented by the directive reveals mitigation strategies that have been tried and proven to lower emissions and improve air quality. Using Italy as a case study, adherence to the NEC directive has been incredibly successful as the 2020 goal of a 65% reduction to a baseline SO2 from 2002 was reached, primarily through reductions in emissions from the switch from coal to natural gas (De Marco, 2019). Similarly, nitrogen dioxide reductions showed a decreasing trend from reductions in road transport (De Marco, 2019). Much of the reductions were attributed to steps taken from the interpretation of data obtained from accurate monitoring which allowed the country to implement strategies to best reduce emissions, rather than follow a blanket reduction plan that may have fit poorly for the country (De Marco, 2019). Monitoring sites were also instrumental in predicting the effects changes to emissions would have in the future and how strategies could be maximized for health and economic benefits (De Marco, 2019)

For Detroit, a similar step should be undertaken as in an EU state. Initially, the state should implement accurate monitoring stations across the city, gathering surveillance and identifying polluters to an accurate degree. While the state of Michigan does have a comprehensive air quality system, only seven stations measure the air quality in the city of Detroit (Walding, 2016). Additional stations are required, specifically around the city's point sources and pollution for more accurate data. Such data would also serve to differentiate where pollutant reductions would be the most beneficial. A contemporary research paper compared multiple reduction strategies for air pollution within the city including reductions on the leading sources of emissions, targeting reductions in areas that have the most health effects, and blanket city-wide levels (Martenies et al, 2018). Using dispersion modeling as a quantitative impact health assessment, the conclusion of the research determined that the most effective strategies ". . . focused on emission sources with the highest health impacts per ton of pollutant emitted provided the greatest health benefit per ton of pollutant reduced" (Martenies et al, 2018). This was in contrast to "strategies targeting the larger emitters increased inequalities and sometimes provided minimal health benefits." (Martenies et al, 2018). The study concluded that blanket reductions on the largest emitters such as those under the EPA plan would prove to be less effective than strategic reduction. A move away from blanket reduction strategies to one of strategic planning based on where emission reduction would ensure the most cost-beneficial and optimized outcome. Following a system like the EU's reduction plan would prove the most effective for Detroit, as it would first establish accurate monitoring sites, which would in turn help to determine where setting reductions from emitters would be the most beneficial. Similarly, additional data gathered could help the city plan where to implement other reforms best, such as investment in public transport.

Conclusion and Notes

Ultimately, the city of Detroit has a long history related to air quality. Owing to its history as a manufacturing base, the city's layout predisposes it to increased susceptibility to negative health outcomes relating to air pollution. Through EPA policies, the city has managed to fall within acceptable pollutant guidelines, but large fluctuations in pollutant levels expose the city's residents to the negative health outcomes associated with air pollutant exposure. The burden of such outcomes is immense and deprives the city of both capital and its citizens of an unperturbed and healthy life. Further, this burden disproportionately affects the city's African American and minority groups, exacerbating the historic and contemporary disparity these groups have experienced. Reduction in air pollution should become a focal point of environmental regulation and activism within the city. Detroit should follow a mitigation strategy tested in Europe. The city should focus on first instituting quantitative measurement sites throughout the city to accurately create a tailor-made plan that creates a balanced and cost-effective reduction strategy rather than following a national blanket emission reduction plan which has historically proven to be ineffective.

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