What Cities are Most Dangerous to your Life Expectancy? Toward a Methodology of Livability

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ABSTRACT

Poor air quality is a major worldwide problem, prematurely killing more people than any other disease. This article proposes a method for identifying toxic air in cities and how it impacts lifespan, fetal health, education scores, housing values, and labor force participation. After collecting U.S. Environmental Protection Agency (EPA) air quality data, we found four standard measures of air quality for medium size cities. We use the Molotch/Appelbaum comparative planning method of looking at 142 midsize cities with populations over 50,000 that are not located within 20 miles (32.2 km) of other similarly-sized cities. The method, results and ranking of midsize cities by cleanest to dirtiest in terms of air quality will inform citizens to understand how to address social, health and economic problems in cities with poor air quality and empower them to support clean air policies. EPA measures are the best available and clash with fraudulent claims of industry insiders that the air quality in specific localities is not toxic. This method aids the medical community in explaining why COVID-19 cases are more prevalent in highly polluted cities.

INTRODUCTION

The Clean Air Act is under assault. While there is some resistance in green cities, most health departments and universities are silent about the ill effects of air pollution. During the Trump administration, the enforcement of clean air regulations was lax. Data on the levels of poor air quality that was once easily obtainable became less accessible. Previously available EPA air quality data is no longer being collected, due to the false belief that disclosing locations with high toxic air hurts economic development.

Air pollution comprises one of the most detrimental environmental human health risks in the world. In 2012, on the authority of the World Health Organization (WHO), recurring exposure to household and ambient air pollutants, such as particulate matter (PM), contributed to the deaths of 7 million people worldwide [1]. Their study considered PM and associated polycyclic aromatic hydrocarbon (PAH) levels in outdoor air, identifying their possible emission sources and analyzing health risks in the city of Tandil, Argentina [1]. Sixteen priority PAHs (categorized as $PM_{2.5}$) were considered to be probable human carcinogens and were listed by the International Agency for Research on Cancer as priority pollutants. The study showed that out of 8,855 Tandil children under 5 years of age, 4 cases of death were attributable to short term outdoor PM_{10} exposure [1].

They also found 21 lethal cases out of the total population of 123,871 people in Tandil. Another study established that exposure to nitrogen dioxide (NO_2), a gaseous air pollutant associated with motor vehicle emissions, is attributed to mortality in a number of time series studies [2]. Their study noted associations between NO_2 and non-accidental, circulatory and respiratory deaths in single-pollutant models [2].

PM_{10} and $PM_{2.5}$ lethality is associated with cardiac and respiratory causes, decreased lung capacity in children and asthmatic adults, and increased chronic obstructive pulmonary diseases [3]. The evidence indicates that the relative estimated risks (based on the EPA criteria document's review of PM_{10} studies) include an increased all-age mortality of 2.5% to 5.0% for each 1 mg/m^3 increase in the PM_{10} concentrations or 25 mg/m^3 increase in the $PM_{2.5}$ concentrations. A study by Leiva et al. ruled out tobacco smoking, passive tobacco smoke exposure, occupational exposure to fine particles, temperature and alcohol use as causes of cerebrovascular hospital admissions [3]. The authors found that fine-particle pollution was related to at least a 15% difference in death rates between the least and most polluted cities. The information also determined that when the $PM_{2.5}$ concentrations increase by 10 mg/m^3, the risk of emergency hospital admissions for cerebrovascular causes increases by 1.29%. The goal of our research is to understand how mid-sized U.S. cities compare to one another in their pollution emissions.

LITERATURE REVIEW

A vast amount of academic research regarding air pollution illustrates its negative effects on quality of life with far-ranging consequences for people of all races, genders, ages, income levels and occupations. These effects can be exacerbated by proximity to higher levels of air pollution. While multiple variables affect the quality of life for the groups discussed, air pollution is a key component. Worldwide, air pollution was responsible for 7 million premature deaths in 2010 [4]. The Organization for Economic Co-operation and Development (OECD) states that by 2050, poor air quality will be the number one cause of premature death rates rising ahead of current primary causes from sanitation and dirty water [5]. A study published in *The Lancet* estimates that 1.2 million premature deaths occur annually in Chinese cities due to air pollution [6-10]. Furthermore, an EPA study showed that a Trump administration proposed rollback of pollution restrictions on coal-fired plants could result in up to 1,400 more premature deaths annually in the U.S. [11].

Air pollution is potentially more damaging to the health of infant children. While much research on the fetal origins hypothesis centers on how undernutrition, disease, and maternal health habits create lasting effects in newborns, a growing base of literature links the proximity to air pollution to adverse health effects in utero [12]. Studies have shown the link between fetal exposure to pollution and higher infant mortality rates as well as the link between reductions in environmental carbon monoxide (CO) and reductions in instances of low birth weight [13-15]. Infants weighing less than 5.5 lbs (2.5 kg) at birth often suffer from early sickness or infections and may have development issues as they age [16]. Each of these studies concur that the proximity of a pregnant mother to higher levels of air pollution has a key role in the health of the newborn child. These effects are found in seemingly healthy babies later in life. Prenatal exposure to a variety of types of air pollution negatively affects academic test scores and economic outcomes later in life [17]. Further work illustrates that adult non-health endpoints are affected as well. Both lower labor force participation and lower earnings are correlated with higher exposure to pollution at birth and later in life [18-19].

Another study determined that a 19.7% decrease in sulfur oxide (SO_X) emissions results in an increase of 3.5% in working hours for immediate neighbors within 3.1 miles (5 km) of a heavy polluter [20]. The finding noted a 6% increase in the probability of those residents working over 40 hours per week and 2.5% increase in the probability of them working over 10 hours per week [20]. Motti's study of Santiago, Chile, found that women's working hours decreased significantly during those weeks of the year with the city's highest levels of pollution though total work hours remained consistent [21]. Montt posits that this discrepancy was due to the likelihood of women assuming the care of children and the elderly, groups who are most likely to be affected by poor air quality [21].

Research literature on environmental justice issues has long established that hazardous sites, including sources of air pollution, are disproportionately located in racial and ethnic minority neighborhoods [8,22-29,61]. There is debate as to whether hazardous industries were relocated to minority neighborhoods or minority population moved to such sites after the hazards were present [27,28]. Recent studies indicate that the hazardous sites were located in minority neighborhoods after racial compositions are established [30-32]. This can be due to the neighborhood's lack of political power or weak real estate markets [33-34]. Consistent evidence supporting the disproportionate impact of environmental contaminants on racial and ethnic minority neighborhoods raises concerns about the possible links to shortened lifespans. Evidence shows that living in countries, states, cities or neighborhoods with high levels of air pollution shortens life expectancies by four to thirteen years [4,6,9].

The world's recent focus on reducing dependency on greenhouse gas (GHG) emitting compounds also helps to reduce other types of air pollution. A study by Burtraw et al. showed that the total short-term health benefits gained through ancillary NO_X and SO_X reductions by taxing all GHGs justifies the initial costs of the tax [35]. Reductions in fossil fuel combustion corresponds with reductions in particulate air pollution [36].

Greenhouse gases trap heat in the Earth's atmosphere, altering the planet's climate. Major sources of GHGs include electric generation and industrial process plants fired with coal, oil and natural gas and vehicles that consume fossil fuels. The co-benefits of reducing GHGs correspond to roughly a half million fewer premature deaths due to other types of air pollution plus a slowing of the effects of global warming by 2030 [37]. The EPA classifies four different types of emissions as GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO) and fluorinated gas (F_2) [38]. The WHO suggests that increases in GHG emissions affect human health by contaminating air and drinking water, spoiling crops, and destroying man-made shelter [39]. This selection of work is only part of the research dedicated to understanding how air pollution affects human health, environmental justice and productivity. While there is much work to be done to fully understand how, why, and where these effects are most costly, it appears that there are significant benefits to living in places with lower air pollution.

METHODOLOGY

Our study methodology involves establishing case selection criterion, identifying a sample of U.S. counties to study, developing a process to exclude certain cases, and selecting and assessing test variables.

Case Selection Criteria

We first established an appropriate case selection criterion. Urban researchers tend to use all available cities for which there is data. Since there is great variety among cities, this approach is known to urban scholars to be misleading. It is problematic to include large metropolises like New York City in a sample set that is dominated by cities with much lower populations. Overly large geographies of metropolitan statistical areas (MSAs) or commuting zones (CZs) are more appropriate for regional research. Most CZs contain multiple counties, such as San Francisco and Chicago which include both generally suburban counties with generally cleaner air and urban counties with more polluted air. Instead, we use the much smaller and generally more consistent unit of county as our level of analysis. The county as the unit of consideration allows for a more granular analysis than the much larger MSAs or CZs. The county-level has the additional benefit of representing entities which are politically governed. The MSAs are too large and the Census tracts too small to provide transferable findings to municipal leaders; findings uncovered at the level of county are more actionable.

The problem of spatial lag occurs in situations where cities are either immediately adjacent to or in close proximity to another city of similar size or larger. As such, they likely share labor, transportation and housing markets. Airborne pollution emissions disregard political boundaries. Neighboring cities are also subject to policy spillovers, in which the impacts of one city's policies can be measured in adjacent jurisdictions. Such factors tend to obscure empirical findings.

To identify an appropriate set of municipalities to study, we draw on Appelbaum's *Size, Growth, and U.S. Citie*s and Molotch's *City as a Growth Machine* [40-41]. What we call the *Molotch/Appelbaum Method* has been replicated by other researchers to predict urban riots, rents, health and happiness [42-45].

Our case selection methodology yields a subset of U.S. cities that we call *semi-isolated, midsize cities*. Selection using this approach begins with the universe of all incorporated places defined by the U.S. Census. The number of cities is further reduced to those cities with populations over 50,000 which are not located within another 20 miles (32.2 km) of another city of a similar size. This results in a subset of (N = 142) semi-isolated, midsize cities.

Excluded Cases

In two instances, one county contained two semi-isolated, midsize cities. In these cases, we kept the larger of the two cities in the list. For example, Bakersfield and Delano are both in Kern County, California. We retained Bakersfield and omitted Delano to avoid double counting the emissions data of Kern County. In Santa Barbara County, California, we kept Santa Barbara and omitted Santa Maria. Four semi-isolated, midsize cities in Virginia were excluded from our comparison: Lynchburg, Richmond, Roanoke and Harrisonburg. These *independent cities* are not politically part of a county, though they may be surrounded by one. We omitted these cities from our analysis to preserve our methodology that uses the county as the unit of comparison.

Test Variables

The U.S. Clean Air Act (CAA) is a federal law, enacted in 1970 and last amended in 1990. It authorized the existence of the EPA and establishing the National Ambient Air Quality Standards (NAAQS). The EPA regulates air emissions from stationary and mobile sources in an attempt to protect public health. The National Emissions Inventory (NEI) is a comprehensive and detailed estimate of air emissions of criteria pollutants and hazardous air pollutants from air emissions sources which is released every three years. State, local, and tribal air agencies provide data which supplements EPA data. The NEI is considered the guiding source for environmental emissions in the U.S. [46].

We gathered the 2011 NEI data for four air pollutants for the selected 142 semi-isolated, midsize cities: PM_{10}, $PM_{2.5}$, NO_x and SO_x. The data file contains the emissions by sector for all U.S. counties. While the EPA has publicly available online tools to query the 2011 NEI data, this tool only presents one location at a time. The data presented is, to our knowledge, the first of its kind in comparing county-level pollution.

POLLUTANTS

Next, we discuss the EPA criteria air pollutants selected for our study of U.S. counties.

Particulate Matter

Particulate matter (PM) is an air pollutant classification based on particle diameters. The EPA provides data on two types. Particulate matter 10 (PM_{10}) is the category for a mixture of solid particles and liquid droplets found in the air that are 10 micrometers or less in diameter. Similarly, $PM_{2.5}$ are particles 2.5 micrometers or less in diameter. These particles are small enough to be inhaled deep within the lungs where they may be deposited and result in adverse health effects.

PM_{10} and $PM_{2.5}$ may be different sizes and shapes and can be composed of hundreds of different chemicals. The chemical properties of PM depend on the source of emission. PM is both a primary and secondary pollutant [47]. Some are emitted from a point source, such as construction sites, unpaved roads, fields, smokestacks or fires. Most particles form in the atmosphere as a result of complex reactions of chemicals such as SOx and NOx, which are pollutants emitted from power plants, industries and motor vehicles with internal combustion engines [48].

PM aerosols affect climate directly by scattering and absorbing solar radiation. This contributes to global warming while reducing the radiation flux at the Earth's surface. Aerosols are also an indirect radiative because the presence of particles in the atmosphere has a role in cloud formation [49]. Adverse health effects related to PM exposure concern mainly respiratory and cardiovascular systems [16,50,51]. There is evidence that PM affects atherosclerosis and leads to adverse birth outcomes. Children and elderly populations are most sensitive to the impacts of exposure to PM [49]. Epidemiological and human exposure studies show that both long- and short-term exposure to PM correlate with cardiovascular and respiratory morbidity and mortality [52]. PM in outdoor air pollution is designated as a Group I carcinogen by the International Agency for Research on Cancer [53]. A study involving 312,944 people in nine European countries revealed that there was no safe level of particulates in the airstream. For every increase of 10 $\mu g/m^3$ in PM_{10} and $PM_{2.5}$, the lung cancer rate rose 22% and 36% respectively [54].

Nitrogen Oxides

Nitrogen oxides are a group of highly reactive and poisonous gases, the most common being nitrogen dioxide (NO_2). Most airborne NO_x comes from combustion-related emissions sources, primarily fossil fuel combustion by electric utilities, high-temperature operations at other industrial sources, and operation of motor vehicles [55]. Nitrogen oxides react with other airborne chemicals to form PM. Exposure to particulate matter aggravates chronic respiratory and cardiovascular diseases, alters host defenses, damages lung tissue, leads to premature deaths, and possibly contributes to cancer [56]. When exposed to the ultraviolet (UV) rays in sunlight, NO_x molecules break apart and form ozone (O_3), a GHG which contributes to smog. Ground-level ozone exacerbates chronic respiratory diseases and causes short-term reductions in lung function [56]. Breathing air with high concentrations of NO_x irritates airways in the human respiratory system. Such exposures over short periods aggravates respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions, and visits to emergency rooms. Longer exposures to elevated concentrations of NO_2 contributes to the development of asthma and potentially increases susceptibility to respiratory infections [55].

Sulfur Oxides

Sulfur oxides (SO_x) are a group of reactive and toxic gases, the most common being sulfur dioxide (SO_2). These are colorless gases that can be detected by taste and smell. SO_x are emitted primarily through fossil fuel combustion (Rankin cycle) processes by power plants and industrial facilities. Other sources of SO_x emissions include: industrial processes such as extracting metal from ore, natural sources such as volcanoes, locomotives, ships, other vehicles and heavy equipment that combust fossil fuels with a high sulfur content. Short-term exposure to SO_x causes harm to the human respiratory system, making breathing difficult [51,56]. Atmospheric SO_x react with water, oxygen, and other chemicals to form damaging PM, and contribute to acid rain by forming sulfuric acid (H_2SO_4).

ANALYSIS: WHICH MIDSIZE CITIES HAVE THE DIRTIEST AIR?

Our research is designed to empower citizens with local information regarding air pollution. A total of 142 midsize cities met our criterion of having populations greater than 50,000, not being located within 20 miles (32.2 km) of another city of 50,000, and with EPA data providing accurate measures of the four types of air pollutants. The public has the right to know which cities have dangerous levels of pollution that can cause health problems and reduce life expectancies. To determine how to retrieve this data for your locale, follow these steps:

Step 1: Download the NEI 2011 data for *All Sectors* from the following link: https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data**.** This file is quite large (over 90MB) when unzipped. The download may take a few minutes.

Step 2: Extract the comma-separated values (CSV) file from the zipped folder and open in Microsoft Excel or an alternative spreadsheet. The following steps may differ when using other types of software.

Step 3: Highlight each column containing data and click the *Filter* button in the top ribbon. The *Filter* button can be found under the *Data* heading in the top ribbon. After completing this step, the top heading of each row (under row A) should appear with a dropdown button.

Step 4: Click the dropdown button in Column D, *St_usps_cd*. This allows you to filter the large amount of data in this file by state. Check only the box for the state in which your city resides. For example, someone searching for emissions data for Indianapolis, Indiana would check only the box next to “IN”.

Step 5: Click the dropdown button in Column F, *County Name*. Check only the box for the county in which your city is located. For example, someone searching for emissions data for Indianapolis, Indiana would check only the box next to “Marion” for “Marion County, Indiana.”

Step 6: Click the dropdown button in Column H, *Pullutant cd*. Check only the box for the pollutant you wish to retrieve data for. For example, someone searching for PM_{10} emissions data (still for Indianapolis, Indiana) would check the box next to *PM10-PRI*.

Step 7: Scroll to the first empty cell under Column K, *Totalemissions*. Highlight the cell and click *Autosum (Σ)* in the top ribbon. Record the calculated number. The *Autosum* ribbon can be found under the home tab and is shown under the Σ. This number is the total emissions for the selected pollutant as estimated by the NEI.
Step 8: Repeat step 6 for each pollutant desired. Record the last number in Column K after completing Step 6 each time. These numbers are the total emissions for each selected pollutant as estimated by the NEI. The last cell with a value in Column K will remain auto-summed even after different pollutants are selected.
Step 9: Compare each value recorded for total emissions by selected pollution Table 1 of this article**.** Steps 4-6 can be repeated for any county, city (using county as proxy), state, and tribal sector as desired. In all cases, higher numbers reflect higher pollution levels.

RANKING MIDSIZE CITIES BY AIR POLLUTION LEVELS

Tables were developed to show the wide variations in levels of air pollution. They also show which cities have dangerously high levels of pollution as measured by the EPA. Table 1A (see Appendix) lists the142 cities and their pollution levels for each of the four considered pollutants. Table 2 shows the 10 cities with the highest and lowest levels of PM_{10}. Table 3 shows the 10 cities with highest and lowest $PM_{2.5}$ levels. Table 4 shows the 10 cities with highest and lowest NO_x levels. Table 5 shows the 10 cities with highest and lowest SO_x levels.

Table 2. PM_{10} emissions (tons).

City	*State*	*County*	*Rank*	*PM_{10}*
Las Cruces	NM	Doña Ana	1	67,065
Santa Fe	NM	Santa Fe	2	65,890
Wichita	KS	Sedgwick	3	39,029
Cheyenne	WY	Laramie	4	35,765
Long View	TX	Gregg	5	28,564
Lubbock	TX	Lubbock	6	28,118
Gulfport	MS	Harrison	7	25,598
Bend	OR	Deschutes	8	24,099
Fargo	ND	Cass	9	23,986
Bakersfield	CA	Kern County	10	23,553
Clarksville	TN	Montgomery	132	3,463
Toms River	NJ	Ocean County	133	3,451
La Crosse	WI	La Crosse	134	3,223
Rocky Mount	NC	Nash	135	3,179
Scranton	PA	Lackawanna	136	3,130

Athens	GA	Clarke	137	2,473
Vineland	NJ	Cumberland	138	2,270
Tyler	TX	Smith	139	2,211
Wilmington	NC	New Hanover	140	1,974
Waco	TX	Mclennan	141	1,759

Table 3. $PM_{2.5}$ emissions (tons).

City	*State*	*County*	*Rank*	*$PM_{2.5}$*
Bend	OR	Deschutes	1	13,802
Bakersfield	CA	Kern County	2	12,208
Santa Fe	NM	Santa Fe	3	10,673
Duluth	MN	St. Louis	4	9,391
Flagstaff	AZ	Coconino	5	8,975
Lake Charles	LA	Calcasieu	6	8,684
Las Cruces	NM	Doña Ana	7	8,346
Mobile	AL	Mobile	8	7,684
Louisville	KY	Jefferson	9	7,672
Wichita	KS	Sedgwick	10	7,182
Vineland	NJ	Cumberland	132	1,168
Clarksville	TN	Montgomery	133	1,156
Evansville	IN	Vanderburgh	134	1,066
Greenville	NC	Pitt	135	1,045
La Crosse	WI	La Crosse	136	1,028
Bloomington	IN	Monroe	137	1,028
Wilmington	NC	New Hanover	138	933
Columbus	GA	Muscogee	139	914
Rocky Mount	NC	Nash	140	906

Athens	GA	Clarke	141	489

Table 4. Oxides of nitrogen emissions (tons).

City	*State*	*County*	*Rank*	*NOx*
Bakersfield	CA	Kern County	1	46,852
Louisville	KY	Jefferson	2	37,796
Jacksonville	FL	Duval	3	36,981
Columbus	OH	Franklin	4	36,846
Pittsburgh	PA	Allegheny	5	35,455
Lake Charles	LA	Calcasieu	6	35,343
Duluth	MN	St. Louis	7	34,183
Mobile	AL	Mobile	8	32,303
Long View	TX	Gregg	9	23,724
Toledo	OH	Lucas	10	23,624
Idaho Falls	ID	Bonneville	132	4,055
Greenville	NC	Pitt	133	3,831
Dubuque	IA	Dubuque	134	3,827
Dothan	AL	Houston	135	3,651
San Angelo	TX	Tom Green	136	3,553
Bloomington	IN	Monroe	137	3,462
Eau Claire	WI	Chippewa	138	3,409
Athens	GA	Clarke	139	3,049
Kokomo	IN	Howard	140	2,685
Manhattan	KS	Riley	141	2,548

Table 5. Oxides of sulfur emissions (tons).

City	*State*	*County*	*Rank*	*SOx*
Terre Haute	IN	Vigo	1	55,945
Lake Charles	LA	Calcasieu	2	41,135

Louisville	KY	Jefferson	3	39,231
Gulfport	MS	Harrison	4	32,925
Sioux City	IA	Woodbury	5	29,693
Jacksonville	FL	Duval	6	20,852
Mobile	AL	Mobile	7	20,673
Green Bay	WI	Brown	8	18,307
Amarillo	TX	Potter	9	15,388
Columbus	GA	Muscogee	132	84
St. George	UT	Washington	133	82
Conway	AR	Faulkner	134	77
Yuba City	CA	Sutter	135	75
Abilene	TX	Taylor	136	72
Laredo	TX	Webb	137	71
Bismarck	ND	Burleigh	138	68
Bowling Green	KY	Warren	139	61
Evansville	IN	Vanderburgh	140	43
Kokomo	IN	Howard	141	35

Table 6 combines the measures of air pollution with one total ranking. This was developed by averaging the rank of each city as determined from Tables 1A and Tables 2-5 using the following equation:

$$CR = (R10 + R25 + RNO_X + RSO_X) \div 4$$

Where: CR = Composite ranking of cleanest and dirtiest cities considered.
R10 = City’s rank among all considered in PM_{10} emissions.
R25 = City’s rank among all considered in $PM_{2.5}$ emissions.
RNO_X = City’s rank among all considered in NO_X emissions.
RSO_X = City’s rank among all considered in SO_X emissions.

Table 6. Composite emissions rank.

City	*State*	*County*	*Rank*
Mobile	AL	Mobile	1
Louisville	KY	Jefferson	2
Lake Charles	LA	Calcasieu	3
Duluth	MN	St. Louis	4
Bakersfield	CA	Kern County	5
Long View	TX	Gregg	6
Gulfport	MS	Harrison	7
Jacksonville	FL	Duval	8
Baton Rouge	LA	East Baton Rouge Parrish	9
Colorado Springs	CO	El Paso	10
Bowling Green	KY	Warren	132
Evansville	IN	Vanderburgh	133
Eau Claire	WI	Chippewa	134
La Crosse	WI	La Crosse	135
Yuba City	CA	Sutter	136
Greenville	NC	Pitt	137
Kokomo	IN	Howard	138
Athens	GA	Clarke	139
Rocky Mount	NC	Nash	140
Columbus	GA	Muscogee	141

THE IMPLICATIONS OF POLLUTION

In April 2016, an issue of *Journal of the American Medical Association* (*JAMA*) listed Louisville, Kentucky was one of the U.S. cities with the shortest life spans among poor men, about 1,643 days shorter than those in Santa Barbara, California [57]. How do you explain this 4.5-year gap in lifespan? The lead author, Raj Chetty, believes that *place* shapes lifespans but fails to identify the causes of such differences (Detroit versus San Francisco also has a 4.5-year gap). The *JAMA* article failed to mention the causes of reduced life expectancy in Louisville and other cities: environmental toxins in the air, water and soil [58]. His own data proved this with a simple observation: Detroit, Gary, Indianapolis, Tulsa, and Louisville have significantly higher air pollution levels when compared with coastal cities like Los Angeles, Santa Barbara, Santa Rosa, San Francisco and New York. This better explains the nearly 5-year difference in life spans among these cities in his tables. The overwhelming evidence shows that if you live in countries, states, cities or neighborhoods with more air pollution, your life will be shortened by 4 to 13 years [4,6,9].

Chetty et al.'s methodological approach of using supersized metropolitan regions with one or more counties diminishes the measure of air pollution's impact on humans [57]. The influence of exposures at the street and neighborhood levels becomes averaged out. Louisville is a good example of why smaller geographic areas should be used: they are where the effects of pollution are most severe. For example, a study released by the city of Metro Louisville found that life expectancies can be as much as 13 years longer in several east-end neighborhoods compared to several neighborhoods on the less affluent west side of town. Our published research shows conclusively that shorter life spans are attributable to: 1) the toxic air pollution emitted from chemical and other industrial plants; 2) the brownfields that dot the communities where these less people live; and 3) the loss of the tree canopy caused by air pollution and other causes [58].

Past research that considered 148 midsize cities revealed that improved health (using four different measures including life span) was correlated with reduced pollution by promoting walking, biking, car sharing and transit instead of single-car occupancy use [59]. Though race and income may shape where you live and work, the major cause of reduced life expectancy is living near unhealthy air, water and soil. Shorter life spans are found in other parts of the southern U.S. where pollution levels are the highest. According to the Centers for Disease Control and Prevention, 73% of U.S. citizens self-report that they are healthy at age 65. This percentage decreases to 62% in Kentucky, Mississippi and Alabama, 63% in West Virginia, 66% in Tennessee, 67% in Arkansas and Louisiana, and 68% in Oklahoma[16]. In Oregon, a state with stronger environmental regulations, including clean air protections ranking in the top third for U.S. states, 78% of those aged 65 rate themselves as healthy. Roughly 55,000 more of those who are 65 in Kentucky feel unhealthy compared to the national average. When Kentucky is compared to the less polluted state of Oregon, one with the country's cleanest water, air and soil, nearly 100,000 Oregonians feel healthier at age 65.

Worldwide, air pollution was responsible for 7 million premature deaths in 2010 according to a study sponsored by the WHO [4]. By 2050, according to the OECD, poor air quality will be the number one cause of premature death rates rising ahead of sanitation and dirty water, which are currently the primary causes [5].

Facts Over Politics

One of the problems is American exceptionalism: that it might be a problem elsewhere, but in the U.S. scientists are often pressured not to attack polluting industries. This problem has been real for the lead author and his colleagues who have been pressured by public officials, industry leaders, and university administrators not to openly criticize polluting industries. Louisville's mayor acknowledged the wide disparity of life spans between different neighborhoods. Nevertheless, the healthy neighborhoods' task force representing foundations, industry, educators and the medical community ignored the connections between urban environmental degradation and health [60].

Instead, those victimized were often blamed. Claims are made that air pollution was not the problem, but rather health issues were caused by lifestyle choices of diet, exercise, smoking, lack of education and income. Such claims cite the *County Health Rankings and Roadmaps* program enacted by the Robert Wood Johnson Foundation (RWJF) in collaboration with the University of Wisconsin Population Health Institute [61]. Through this program, communities can identify and implement solutions that make it easier for people to be healthy in their schools, workplaces and neighborhoods. Tracking nearly every county in the nation, these rankings illustrate a more subjective view as to what impacts the health of those living in the nation's counties [61]. The program supports the argument that the impact of air, water, housing and transit pollution has a meager impact (only 10%) on a person's health.

Among the most serious problems with the County Health Rankings and Roadmaps is they exclude three of the four EPA primary measures. Findings are based solely on levels of $PM_{2.5}$ which misrepresents each county's air quality and shows only negligible differences among counties in air quality. Our analysis shows that when the impacts of the four EPA measures are combined, there are wide differences in air quality and the impacts of toxic air measurements are minimized. Efforts to correct these methodological errors have been rejected. Moreover, it contributes to arguments published in the world's leading medical journals (e.g., Lancet and JAMA) that inaccurately suggest that local air pollution in the U.S. is not a serious medical concern [57, 61].

The RWJF endorsed and helped fund the Louisville study. We obtained a copy of the data set, which allowed us to test it and insert additional control variables that measure environmental toxins (e.g., location of industrial polluters with high EPA negative scores and identified toxic brownfield sites). In Louisville, our regression analysis, teases out the net impacts of each factor, showing that proximity to polluted areas is as important as race and income in explaining the shortened lives in certain Louisville neighborhoods [58].

Limitations of the Methodology Applied

The utility of this methodology in predicting shortened lifespans in midsize, semi-isolated cities is limited to the availability of the EPA data and using all four measures of pollution together as one. In midsize, semi-isolated cities for which the EPA data is available, this methodology provides a means of determining how pollution impacts people's lives. By utilizing all four measures of pollution, it provides a more accurate picture than the RWJF study or the County Health Rankings and Roadmaps program, which uses only one air quality measure [61]. The same methodology has been used for predicting high COVID-19 rates in cities and confirming the relationship between high levels of air pollution and the number of virus cases [62,63]. This methodological tool is not appropriate for large cities or cities that lack EPA guidelines or measurements.

CONCLUSION

Livability indexes are often flawed because they do not accurately measure quality of life or account for the significant impacts of pollution on the livability of neighborhoods and cities. The problem is that pollution is either not included in the livability index or it is minimized or mismeasured. Perhaps pollution is often ignored because it is sometimes invisible to the naked eye.

Published research has tested whether high pollution levels impact health, neighborhoods and cities. First, one study found that pollution has an independent effect of reducing life expectancies (i.e., with differences in groups of poor people, of 5 years for men, and of 4 years for women). Another study found a similar impact when controlling for levels of smoking, drinking, and walkability. Both regression models yielded similar results. Instead of confronting environmental pollution of air and soil and their adverse effects on life spans, billions of dollars are expended in search of treatments and cures, which often means more cutting, gadgets, implants, radiation and pills. In the field of urban sustainability, these external costs are substantial.

Our research offers a more comprehensive assessment. There were 142 midsize cities that met our research criterion of having populations greater than 50,000 and were not located near of another city of similar size. We obtained EPA data that providing accurate measures for four types of criteria air pollutants (i.e., PM_{10}, $PM_{2.5}$, NO_x and SO_x). Using this data set, we proved that pollution has a negative impact on life expectancy. Focusing on one highly polluted city which we ranked number two among 142 cities, we confirmed that high levels of pollution cause a reduced life expectancy. A study found that Louisville lost five years in life expectancy [57]. The Louisville Public Health Department found that citizens near high levels of pollution in Louisville's West End lost anywhere from 10 to 12 years of life expectancy whether in nearly all black or white neighborhoods [64].

Part of the cure for many of our cities is to monitor and reduce pollution in the air, water, soil, streets, and plant more trees. We recommend that all cities have EPA professional pollution monitoring stations. The external costs of $PM_{2.5}$ and PM_{10} emissions are substantial. It is notable that there are few studies showing the separate, individual effects of unique pollutants encompassed within $PM_{2.5}$ and PM_{10} emissions. These airborne pollutants travel together, so it is very difficult to isolate the effects of each constituent found in $PM_{2.5}$ and PM_{10}. It could be that combined pollutants amplify and intensify the ruinous effects of others. Most past studies only measured the environmental levels of $PM_{2.5}$ and $PM_{10,}$ and correlated them with rises in certain adverse health conditions in the surrounding affected area without a control. In addition, the investigations into the pollutant effects were limited to shorter lag times, most likely due to budget and time constraints.

We need to adjust our thinking to be more proactive instead of reactive in resolving public health issues that are associated with pollution. As the Physicians for Social Responsibility point out, we should be "preventing what we cannot cure" [65]. One such preventive measure is ensuring that our communities, including our poor inner-city neighborhoods, enjoy a healthy environment. A cleaner environment also addresses the challenge of climate change, since reductions in pollution from the use of fossil fuels also reduces GHG emissions. It is a win-win for everyone and improves our stewardship of fragile Earth. You might believe that Flint, Michigan is an exception, but there are many cities similar to Flint in the U.S. and Louisville is among them. Proponents of environmental protection need to shift the focus on healthy life expectancies, asking why so many people—especially in the southern states—needlessly die too soon.

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APPENDIX

Table 1A. 2011 NEI data for semi-isolated, midsize U.S. cities (emissions in tons).

U.S. City	*State*	*County*	*PM10*	*PM2.5*	*NO_X*	*SO_X*
Anchorage	AK	Anchorage	8,134	1,916	12,298	429
Auburn	AL	Lee	9,088	3,229	5,193	743
Dothan	AL	Houston	7,492	2,140	3,651	543
Mobile	AL	Mobile	19,680	7,684	32,303	20,673
Montgomery	AL	Montgomery	9,367	4,298	10,725	2,042
Tuscaloosa	AL	Tuscaloosa	14,534	5,254	16,958	2,072
Conway	AR	Faulkner	9,772	1,958	4,314	77
Fort Smith	AR	Sebastian	7,584	2,317	4,487	272
Jonesboro	AR	Craighead	13,140	2,632	4,599	166
Flagstaff	AZ	Coconino	17,829	8,975	17,341	670
Lake Havasu City	AZ	Mohave	12,761	1,547	15,846	134
Yuma	AZ	Yuma	9,223	1,733	8,366	86
Bakersfield	CA	Kern County	23,553	12,208	46,852	3,072
Salinas	CA	Monterey	8,217	2,965	13,398	470
Santa Barbara	CA	Santa Barbara	5,524	1,578	10,285	441

Yuba City	CA	Sutter	3,698	1,189	5,340	75
Chico	CA	Butte	7,248	3,038	7,771	181
Redding	CA	Shasta	5,948	2,858	9,435	205
Colorado Springs	CO	El Paso	15,106	4,499	21,605	9,599
Grand Junction	CO	Mesa	4,352	1,416	7,412	109
Pueblo	CO	Pueblo	7,703	1,915	12,670	3,241
Gainesville	FL	Alachua	8,740	3,050	9,247	2,329
Jacksonville	FL	Duval	12,427	5,542	36,981	20,852
Pensacola	FL	Escambia	9,416	3,731	16,620	3,038
Tallahassee	FL	Leon	8,418	3,565	7,469	388
Albany	GA	Dougherty	5,591	2,367	5,145	1,706
Athens	GA	Clarke	2,473	489	3,049	250
Augusta	GA	Richmond	7,008	2,489	10,092	4,295
Columbus	GA	Muscogee	3,729	914	4,292	84
Savannah	GA	Chatham	7,135	2,281	16,308	10,944
Valdosta	GA	Lowndes	8,780	2,353	5,755	784
Ames	IA	Story	7,672	1,823	5,791	3,536
Davenport	IA	Scott	9,318	2,326	8,111	5,295
Dubuque	IA	Dubuque	9,764	1,962	3,827	1,068
Sioux City	IA	Woodbury	10,854	3,512	16,738	29,693
Waterloo	IA	Black Hawk	9,499	2,089	4,684	387
Idaho Falls	ID	Bonneville	12,900	2,198	4,055	143
Pocatello	ID	Bannock	9,494	1,545	4,985	93
Champaign	IL	Champaign	17,812	3,434	7,775	630
Decatur	IL	Macon	13,599	2,976	8,306	12,928
Peoria	IL	Peoria	11,023	2,565	11,308	14,213
Rockford	IL	Winnebago	9,309	2,225	7,319	439
Springfield	IL	Sangamon	14,756	3,428	8,424	3,385
Bloomington	IN	Monroe	5,701	1,028	3,462	1,511
Evansville	IN	Vanderburgh	5,659	1,066	6,271	43

Fort Wayne	IN	Allen	13,759	2,736	14,789	272
Kokomo	IN	Howard	6,288	1,341	2,685	35
Lafayette	IN	Tippecanoe	10,478	2,213	8,074	7,522
Terre Haute	IN	Vigo	12,547	4,570	12,046	55,945
Manhattan	KS	Riley	9,440	3,427	2,548	316
Wichita	KS	Sedgwick	39,029	7,182	18,153	197
Bowling Green	KY	Warren	5,489	1,524	5,735	61
Lexington	KY	Fayette	8,341	1,772	7,845	582
Louisville	KY	Jefferson	15,898	7,672	37,796	39,231
Owensboro	KY	Daviess	6,096	1,583	7,656	9,014
Baton Rouge	LA	E. Baton Rouge Parrish	12,872	5,832	22,052	11,812
Lafayette	LA	Lafayette Parish	5,556	1,953	8,954	1,324
Lake Charles	LA	Calcasieu	14,668	8,684	35,343	41,135
Shreveport	LA	Caddo Parish	8,618	3,593	19,620	1,859
Frederick	MD	Frederick	4,683	1,482	6,816	439
Portland	ME	Cumberland	6,652	2,807	11,792	3,429
Ann Arbor	MI	Washtenaw	9,072	2,786	11,616	189
Flint	MI	Genesee	10,732	3,119	12,293	176
Saginaw	MI	Saginaw	12,099	3,216	6,469	524
Lansing	MI	Ingham	8,076	2,340	9,906	7,625
Duluth	MN	St. Louis	21,556	9,391	34,183	7,032
Rochester	MN	Olmsted	8,860	3,138	6,362	651
St. Cloud	MN	Stearns	11,372	3,916	7,607	280
Columbia	MO	Boone	12,699	2,261	7,703	7,024
Joplin	MO	Jasper	13,312	2,697	6,189	9,068
Springfield	MO	Greene	19,321	3,773	13,432	8,840
St. Joseph	MO	Buchanan	6,199	1,251	6,658	2,014
Gulfport	MS	Harrison	25,598	4,892	16,468	32,925
Jackson	MS	Hinds	20,162	2,887	9,550	87
Billings	MT	Yellowstone	18,823	3,927	10,656	7,515
Great Falls	MT	Cascade	11,310	1,957	4,331	104

Missoula	MT	Missoula	17,843	5,981	5,425	388
Asheville	NC	Buncombe	4,295	1,536	8,663	2,679
Fayetteville	NC	Cumberland	4,600	1,365	8,318	287
Greenville	NC	Pitt	3,513	1,045	3,831	184
Jacksonville	NC	Onslow	3,746	1,596	4,434	827
Rocky Mount	NC	Nash	3,179	906	4,412	100
Wilmington	NC	New Hanover	1,974	933	9,946	13,844
Bismarck	ND	Burleigh	8,057	1,422	4,338	68
Fargo	ND	Cass	23,986	5,616	10,234	892
Grand Forks	ND	Grand Forks	13,535	3,257	4,776	816
Grand Island	NE	Hall	10,442	2,187	7,378	2,378
Lincoln	NE	Lancaster	19,193	3,402	16,990	4,254
Manchester	NH	Hillsborough	6,574	3,165	7,602	1,464
Toms River	NJ	Ocean County	3,451	1,711	7,970	493
Vineland	NJ	Cumberland	2,270	1,168	4,132	696
Las Cruces	NM	Doña Ana	67,065	8,346	11,506	209
Sante Fe	NM	Santa Fe	65,890	10,673	6,936	382
Rochester	NY	Monroe	10,599	3,652	16,726	6,959
Syracuse	NY	Onondaga	9,483	2,856	12,533	3,574
Utica	NY	Oneida	8,305	2,763	5,378	1,115
Akron	OH	Summit	6,237	2,128	17,500	4,311
Canton	OH	Stark	7,858	2,712	15,163	567
Columbus	OH	Franklin	14,690	4,802	36,846	441
Toledo	OH	Lucas	6,650	2,986	23,624	12,715
Youngstown	OH	Mahoning	4,664	1,361	9,362	1,481
Lawton	OK	Comanche	16,193	4,320	6,607	385
Bend	OR	Deschutes	24,099	13,802	6,486	858
Medford	OR	Jackson	14,086	5,976	6,844	612
Salem	OR	Marion	16,848	6,615	10,074	676
Erie	PA	Erie	5,825	2,444	11,373	1,659
Lancaster	PA	Lancaster	17,405	5,402	13,810	1,209

Pittsburgh	PA	Allegheny	8,892	5,740	35,455	15,080
Reading	PA	Berks	10,868	4,486	14,404	5,669
Scranton	PA	Lackawanna	3,130	1,567	5,840	459
Columbia	SC	Richland	9,225	3,536	16,035	8,343
Greenville	SC	Greenville	11,060	3,035	12,860	657
Rapid City	SD	Pennington	10,801	4,660	6,813	1,047
Sioux Falls	SD	Minnehaha	12,158	2,453	5,918	425
Chattanooga	TN	Hamilton	3,469	1,514	14,444	833
Clarksville	TN	Montgomery	3,463	1,156	5,103	479
Jackson	TN	Madison	5,209	2,014	5,938	238
Knoxville	TN	Knox	7,315	1,974	17,137	567
Albilene	TX	Taylor	12,659	1,954	5,053	72
Amarillo	TX	Potter	10,952	2,541	13,531	15,388
Corpus Christi	TX	Nueces	16,912	5,547	18,528	1,518
El Paso	TX	El Paso	16,915	3,025	19,152	588
Laredo	TX	Webb	6,368	1,312	16,967	71
Long View	TX	Gregg	28,564	5,507	23,724	8,489
Lubbock	TX	Lubbock	28,118	4,694	8,854	143
San Angelo	TX	Tom Green	12,970	2,856	3,553	204
Tyler	TX	Smith	2,211	1,569	8,076	634
Victoria	TX	Victoria	13,612	2,315	7,104	106
Waco	TX	Mclennan	1,759	1,240	11,661	1,305
Wichita Falls	TX	Wichita	9,694	2,156	9,398	617
St. George	UT	Washington	10,955	1,560	4,937	82
Bellingham	WA	Whatcom	5,683	3,078	10,781	8,011
Yakima	WA	Yakima	9,923	3,613	8,904	193
Eau Claire	WI	Chippewa	5,280	1,575	3,409	118
Green Bay	WI	Brown	7,120	2,383	14,161	18,307
Janesville	WI	Rock	8,587	2,454	6,524	85
La Crosse	WI	La Crosse	3,223	1,028	4,500	220
Madison	WI	Dane	18,012	5,277	18,777	1,769

Charleston	WV	Kanawha	8,530	3,090	15,449	13,365
Casper	WY	Natrona	21,919	3,583	5,047	394
Cheyenne	WY	Laramie	35,765	4,924	11,922	348