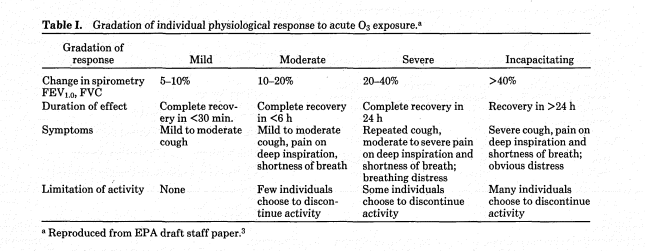
**Intro:**

Air pollution from vehicular traffic and industrial sources is an urgent public health issue which affects populations throughout the country. Pollutants such as PM 2.5, ground level ozone, and carbon monoxide are created from a multitude of sources ranging from vehicular emissions, uncombusted fuel, chemical reactions of various compounds with sunlight, and dust/debris that’s broken down and moved into the air from traffic. These pollutants are all measured and aggregated into an Air Quality Index (AQI). These molecules/compounds are responsible for a variety of health issues affecting the lungs/oxygen intake, can exacerbate pre-existing health issues, and make individuals more susceptible to negative health outcomes in the future. Poor air quality affects low income/immigrant populations at a disproportionate percentage compared to the total populace, which has contributed to truly tragic health outcomes for this group in the ongoing Covid-19 pandemic. Informing and empowering local populations at the neighborhood level about their local air quality conditions can hopefully allow them to modify their behavior and avert/mitigate exposure.

**Ground Level Ozone Creation/Negative Health Effects:**

Ground level ozone/tropospheric ozone is created when oxides of nitrogen (NOx) and volatile organic compounds (VOC) mix and react with heat and sunlight. Atmospheric NOx is created naturally through anaerobic biological processes, lightning, and volcanic activity while anthropogenically generated NOx is caused by the combustion of fossil fuels in power plants, industrial processes, and home heaters. Ground level ozone is the primary component of smog. Concentrations of ozone/smog tend to peak in midafternoon and have higher average levels in the summer compared to the winter. The symptoms of ozone exposure depend on the length of time and concentrations that an individual was exposed to. Mild exposure can lead to coughing, throat dryness, eye and chest discomfort, thoracic pain, and headaches while severe exposure can lead to severe coughing and respiratory pain. Symptoms are reversible after time away from higher concentrations, but there are some studies which show an accelerated loss of lung function over time correlated to high levels of ground level ozone in the atmosphere.



Taken from Health effects of ozone. A critical review

**PM 2.5 Creation/Negative Health Effects:**

PM is short for “particulate matter”. Particulate matter can be anything and everything from solid or liquid particles suspended in the air like dust, dirt, soot, smoke, compounds created through chemical processes in the atmosphere, biological contaminants, etc. (Particulate Matter (PM) Basics). While all air pollution is unpleasant and can have negative health effects, smaller particles like PM 10 or PM 2.5 are much more hazardous to human health. Particulate Matter classified as PM10 is 10 micrometers or smaller. PM2.5 are fine particles which are 2.5 micrometers or smaller. (Particulate Matter (PM) Basics). These particles have long half lives and their small size allows them to stay suspended in the atmosphere or even spread to other locations away from where their points of origin. These smaller sized particles are dangerous because they can be easily inhaled and enter the lungs and bloodstream of unsuspecting individuals. In urban areas large amounts of PM2.5 originate from the transportation sector. Cars, buses, or other vehicles create PM2.5 particles through combustion of fossil fuels, wear and tear on brakes and tires, and from kicking up dust from the movement of traffic. These PM2.5 emissions are clustered in or near arterial roadways. (Askariyeh et al, 2020).

Long term exposure to PM2.5 long term can lead to increased morbidity and mortality from respiratory or cardiovascular diseases. Other harmful linkages between PM2.5 and health include cancer, low birth weight, diseases which affect the central nervous system, development of diabetes, increases in development of lung cancer, and decreased life expectancy (Requia et al, 2018) Worldwide it is responsible for approximately 2.9 million deaths according to a Lancet 2013 global burden of disease study (Forouanzar et al, 2015). Another study estimates the human and economic costs of traffic related PM2.5 emissions in the Greater Toronto and Hamilton Area to be 206 deaths per year from PM 2.5 pollution with 119 of those attributable to cardiovascular issues. The ongoing yearly economic impact is a loss of $1.3 billion and $778 million respectively. (Requia et al, 2018). In the NYC region PM2.5 pollution from on-road sources contributes to approximately 320 deaths and 870 hospitalisations annually, with high poverty neighborhoods sharing more of this burden than low poverty neighborhoods (Kheirbek et al, 2016).

**Carbon Monoxide Creation/Negative Health Effects:**

Carbon Monoxide (CO) gas is created from the incomplete burning of carbon based fuels. The majority of the CO emissions are from mobile sources, such as cars, trucks, motorcycles, farm equipment, construction equipment, aircraft, and marine vessels. Since the majority of emissions are from these mobile sources, the majority of CO pollution is gathered around these sources as well. Cities or other areas with heavy traffic congestion have heavy concentrations of CO pollution. CO can also be generated from industrial processes and natural processes such as forest wildfires. (EPA Carbon Monoxide Explainer)

High levels of CO exposure can be very dangerous. Carbon Monoxide competes with oxygen for binding sites on hemoglobin, this competition results in decreased oxygen transport and release. This then results in hypoxia, loss of consciousness, neurological damage, or even death if the CO is in large quantities for long periods of time (Townsend and Maynard, 2002). The effects of prolonged exposure to lower concentrations are more difficult to determine. There are studies which show an increased correlation between an increase in ambient carbon monoxide levels with heart failure among the elderly, correlations between maternal exposure to CO and low birth weight, and decreased cognitive function (Townsend and Maynard, 2002).

**COVID, Air Pollution, and Poverty:**

Air pollution is not evenly distributed, high poverty neighborhoods experience a “larger share of the exposure and health burden than low poverty neighborhoods” (Kheirbek et al, 2016). Minority groups and others in poverty suffer at higher rates from “social and behavioral determinants of health”, and are also at higher risk of exposure to traffic related air pollution due to their proximity to major highways. There is evidence suggesting that these factors have a “multiplicative interaction” which causes worse health effects from exposure to air pollution. (CDC Health Disparities and Inequalities Report, 2013). These interactions have had deadly consequences over the last few years with the arrival of Covid-19.

A study in Germany showed that a “one standard deviation increase in the three-day average PM10 concentration (7.2 μg/m3) over the period between two and four days after the onset of illness increases the number of deaths among male patients by about 1.2 deaths per 100K members of the population per day, or about 19 percent of a standard deviation. Effect patterns for women are similar, yet less pronounced. Additionally, we find that air pollution just before as well as after the onset of illness leads to increased numbers of confirmed cases across the entire age distribution” (Ishpording and Pestel, 2021). A similar study in the US showed that covid cases and deaths rose significantly in counties with 6 or more Toxic Release Inventory sites by 53.1% and 10.5% respectively after the EPA rolled back enforcement of environmental regulations (Persico and Johnson, 2020). Early warning and knowledge of air pollution could help bring attention to its negative effects and encourage changes in behavior to avoid it amongst the general populace.

**Awareness of AQI and Behavioral Responses:**

Literature on the topic mentions a “perception gap” between public knowledge of air quality and that of experts. Members of the general public rely more on sensory cues such as “visibility and density of pollutant”, or on cues they can smell. Their ideas as to the causes of air pollution depend on their local and cultural contexts; respondents from London identified “cars, buses, HGV's and pollen as the most significant causes of air pollution, while respondents in a poor neighborhood in Nairobi mostly pointed to road dust, industrial areas and burning trash”. Communities in California identify smoke caused by wildfires as pollution, while Indian’s believed that smoke from ceremonial fires could be purifying so long as good fuel is used. Respondents tended to associate air quality as problems that affected other communities more than their own, and often downplayed the negative effects of air pollution on themselves (Noël et al, 2021).

Prior exposure to periods of poor AQI in Ningbo, China “enabled the local residents to have a better understanding of ambient air pollution”. Many residents had a general awareness of air quality, and two thirds of the residents took action to protect themselves during periods of poor air quality. (Qian et al, 2016). In Mexico City awareness of the local air quality index was 53%, with respondents who themselves had a respiratory illness or had a member of their household have a respiratory illness were 14% more likely to be aware of the AQI index. Respondents who had a healthcare provider discuss the air quality index with them were also more likely to be aware of the index. (Study suggested that healthcare providers talking about AQI was more likely to be a positive intervention). In comparison to the residents of Ningbo, only 35% of respondents modified their behavior in response to poor air quality, and residents who had respiratory illnesses or had household members with respiratory illnesses were no more likely to modify their behavior in response to poor air quality. (Borbet et al, 2018). A California study found that when AQI alerts were issued, members of the general public changed their behavior on the first day of the alert only; if the alert was issued for multiple days there was no change in behavior on the second or third days. (Zivin et al, 2009).

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**Links to all sources found on these topics:**

These links cover a wide variety of topics related to:

* Health effects of ground level ozone, carbon monoxide, and PM2.5 on human health
* Environmental justice/relationships between poverty and negative health effects from air pollution and Covid-19
* Perception of air quality in a variety of locales and how people respond to it
* Efforts to create low cost sensor systems to locally monitor AQI
* Various methods used to monitor air quality

Some of these were used/referenced in the paper above, many were not. This list is not exhaustive, and should instead serve as a jumping off point for anyone/group looking to learn more about air pollution and air quality monitoring

Pandemic meets pollution: Poor air quality increases deaths by COVID-19

<https://pubmed.ncbi.nlm.nih.gov/33850337/>

The Effects of Increased Pollution on COVID-19 Cases and Death

<https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3633446>

The contribution of motor vehicle emissions to ambient fine particulate matter public health impacts in New York City: a health burden assessment (Environmental Health, 2016)

<https://ehjournal.biomedcentral.com/articles/10.1186/s12940-016-0172-6>

Residential Proximity to Major Highways (CDC, 2010)

<https://www.cdc.gov/mmwr/preview/mmwrhtml/su6203a8.htm>

City of Chicago Air Quality and Health Report 2020 (Chicago Dept. of Public Health, 2020)

<https://www.documentcloud.org/documents/7035547-2020-7-26-CDPH-Air-Quality-and-Health-Report.html>

Research on Health Effects from Air Pollution (EPA)

<https://www.epa.gov/air-research/research-health-effects-air-pollution>

Environmental and Health Impacts of Air Pollution: A Review (Frontiers in Public Health, 2020)

<https://www.frontiersin.org/articles/10.3389/fpubh.2020.00014/full>

Near-Road Traffic-Related Air Pollution: Resuspended PM 2.5 from Highways and Arterials

<https://pubmed.ncbi.nlm.nih.gov/32326193/>

The health impacts of weekday traffic: A health risk assessment of PM 2.5 emissions during congested periods

<https://pubmed.ncbi.nlm.nih.gov/29220727/>

The contribution of motor vehicle emissions to ambient fine particulate matter public health impacts in New York City: a health burden assessment

<https://ehjournal.biomedcentral.com/articles/10.1186/s12940-016-0172-6>’

Ozone Pollution: A Major Health Hazard Worldwide

<https://www.frontiersin.org/articles/10.3389/fimmu.2019.02518/full>

Residential Proximity to Major Highways — United States, 2010

<https://www.cdc.gov/mmwr/preview/mmwrhtml/su6203a8.htm>

Proximity to roads, NO2, other air pollutants and their mixtures

<https://www.ncbi.nlm.nih.gov/books/NBK361807/>

ALA State of the Air Report

<https://www.lung.org/research/sota/key-findings>

Days of haze: Environmental information disclosure and intertemporal avoidance behavior☆

<https://www.sciencedirect.com/science/article/abs/pii/S0095069609000370?via%3Dihub>

Social awareness of air quality information

<https://pubmed.ncbi.nlm.nih.gov/10535126/>

Knowledge and perceptions of air pollution in Ningbo, China

<https://pubmed.ncbi.nlm.nih.gov/27816059/>

Association of self-reported leisure-time physical inactivity with particulate matter 2.5 air pollution

<https://pubmed.ncbi.nlm.nih.gov/19681386/>

Health effects of ozone. A critical review

<https://pubmed.ncbi.nlm.nih.gov/2659744/>

Effects on health of prolonged exposure to low concentrations of carbon monoxide

<https://oem.bmj.com/content/59/10/708>

# Particulate Matter (PM) Basics

# <https://www.epa.gov/pm-pollution/particulate-matter-pm-basics>

Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013

<https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)00128-2/fulltext>

The health impacts of weekday traffic: A health risk assessment of PM2.5 emissions during congested periods

<https://www.sciencedirect.com/science/article/pii/S0160412017318263?via%3Dihub#bb0080>

Personal strategies to minimise effects of air pollution on respiratory health: advice for providers, patients and the public

<https://erj.ersjournals.com/content/55/6/1902056>

City specific air quality warnings for improved asthma self management

<https://www.ajpmonline.org/article/S0749-3797(19)30193-X/pdf>

Qualitative research about public health risk perceptions on ambient air pollution. A review study

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8325091/>

Social media as a sensor of air quality and public response in China

<https://pubmed.ncbi.nlm.nih.gov/25831020/>

Using Social Media Mining and PLS-SEM to Examine the Causal Relationship between Public Environmental Concerns and Adaptation Strategies

<https://pubmed.ncbi.nlm.nih.gov/34063459/>

Monitoring air pollution: use of early warning systems for public health

<https://pubmed.ncbi.nlm.nih.gov/21942967/>

Air pollution perception in ten countries during the COVID-19 pandemic

<https://pubmed.ncbi.nlm.nih.gov/34155609/>

Assessing air quality index awareness and use in Mexico City

<https://pubmed.ncbi.nlm.nih.gov/29688852/>

Association of self-reported leisure-time physical inactivity with particulate matter 2.5 air pollution

<https://pubmed.ncbi.nlm.nih.gov/19681386/>

Days of haze: Environmental information disclosure and intertemporal avoidance behavior

<https://www.sciencedirect.com/science/article/pii/S0095069609000370>

From a Low-Cost Air Quality Sensor Network to Decision Support Services: Steps towards Data Calibration and Service Development

<https://pubmed.ncbi.nlm.nih.gov/34062961/>

Improving accuracy of air pollution exposure measurements: Statistical correction of a municipal low-cost airborne particulate matter sensor network  
<https://pubmed.ncbi.nlm.nih.gov/33120139/>

Node-to-node field calibration of wireless distributed air pollution sensor network

<https://pubmed.ncbi.nlm.nih.gov/28951042/>

Advantages and challenges of the implementation of a low-cost particulate matter monitoring system as a decision-making tool

<https://pubmed.ncbi.nlm.nih.gov/31650385/>

Calibrating low-cost sensors for ambient air monitoring: Techniques, trends, and challenges

<https://pubmed.ncbi.nlm.nih.gov/33887275/>

Calibration Method for Particulate Matter Low-Cost Sensors Used in Ambient Air Quality Monitoring and Research

<https://pubmed.ncbi.nlm.nih.gov/34201377/>

A land use regression model using machine learning and locally developed low cost particulate matter sensors in Uganda

<https://pubmed.ncbi.nlm.nih.gov/34043968/>

Establishing A Sustainable Low-Cost Air Quality Monitoring Setup: A Survey of the State-of-the-Art

<https://pubmed.ncbi.nlm.nih.gov/35009933/>

Can commercial low-cost sensor platforms contribute to air quality monitoring and exposure estimates?

<https://pubmed.ncbi.nlm.nih.gov/28038970/>

Development and Application of a Next Generation Air Sensor Network for the Hong Kong Marathon 2015 Air Quality Monitoring

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4801587/>

Applications of low-cost sensing technologies for air quality monitoring and exposure assessment: How far have they gone?

<https://pubmed.ncbi.nlm.nih.gov/29704807/>

A Survey of Wireless Sensor Network Based Air Pollution Monitoring Systems

<https://pubmed.ncbi.nlm.nih.gov/26703598/>

Probabilistic Deep Learning to Quantify Uncertainty in Air Quality Forecasting

<https://pubmed.ncbi.nlm.nih.gov/34884011/>

Optimization-Based Approaches for Minimizing Deployment Costs for Wireless Sensor Networks with Bounded Estimation Errors

<https://pubmed.ncbi.nlm.nih.gov/34770428/>

Localized real-time information on outdoor air quality at kindergartens in Oslo, Norway using low-cost sensor nodes

<https://pubmed.ncbi.nlm.nih.gov/29106951/>

Analysing the performance of low-cost air quality sensors, their drivers, relative benefits and calibration in cities-a case study in Sheffield

<https://pubmed.ncbi.nlm.nih.gov/30671683/>

The changing paradigm of air pollution monitoring

<https://pubmed.ncbi.nlm.nih.gov/23980922/>

Deployment, Calibration, and Cross-Validation of Low-Cost Electrochemical Sensors for Carbon Monoxide, Nitrogen Oxides, and Ozone for an Epidemiological Study

<https://pubmed.ncbi.nlm.nih.gov/34205429/>

Predicting hourly air pollutant levels using artificial neural networks coupled with uncertainty analysis by Monte Carlo simulations

<https://pubmed.ncbi.nlm.nih.gov/23292230/>

End-user perspective of low-cost sensors for outdoor air pollution monitoring

<https://pubmed.ncbi.nlm.nih.gov/28709103/>

Field performance of a low-cost sensor in the monitoring of particulate matter in Santiago, Chile

<https://link.springer.com/article/10.1007/s10661-020-8118-4>

Field calibration of a cluster of low-cost available sensors for air quality monitoring. Part A: Ozone and nitrogen dioxide

<https://www.sciencedirect.com/science/article/pii/S092540051500355X>

Field calibration of a cluster of low-cost commercially available sensors for air quality monitoring. Part B: NO, CO and CO2

<https://www.sciencedirect.com/science/article/pii/S092540051631070X>