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A Breath of Fresh Air: Community-Driven Co_2 Filtration for Cleaner Urban Environments

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RESEARCH QUESTION:

To what extent can community-based, low-cost air filtration and CO_2 monitoring currently deployed reduce local air pollution and enhance public health awareness among the most risk-prone, low-income neighborhoods in New York City?

MISSION:

This research aims to provide a solution to the air pollution crisis impacting New York City and the citizens residing there. The rising air pollution in New York City can be combated through the development and deployment of a cost-effective, portable air filtration system that improves air quality and promotes public health. Through focusing on low-income and high-traffic areas, we aim to target hazardous CO_2 exposure in the areas where it is most prominent, raise public consciousness, and create healthier, more balanced communities through collaboration with local government and public health community stakeholders.

IMPACT:

The current research seeks to link the fields of environmental justice, public health, and urban innovation through the application of a cost-efficient, modular device intended for air filtration and monitoring. Technical, social, and policy-related outcomes are envisioned.

The device is expected to achieve a 15–30% reduction in localized CO_2 levels during rush hours, depending on the absorption characteristics of materials like sodium hydroxide or activated carbon. With the incorporation of NDIR sensors, the system hopes to record a deviation of below 5% in CO_2 readings compared to standard EPA-grade sensors. With sustainable operation measures in place using solar panels or rechargeable batteries, the system is expected to have a minimum of 90% uptime during field deployment.

The project highlights social elements, namely improved access and improved awareness.

Through providing people with real-time air quality information using QR-code panels, the project hopes to ensure that over 60% will recognize improvement within their awareness about pollution and its related impacts on health. Additionally, there is expected to be continued use of the site as more than 50% of QR code scans are estimated to be from repeat visitors, indicating ongoing usage by people interested in environmental information.

From a policy standpoint, the real-time environmental information provided by the system can function as a valuable tool for municipal governments. This information can potentially improve land-use planning, traffic management, and public health initiatives in those sections of the city with high levels of pollution, like East Harlem and the South Bronx. If the project proves beneficial, it can justify increased citywide investment in neighborhood-based air quality initiatives and set a model for other municipalities facing similar environmental health challenges.

This project's aim is to demonstrate how technological innovation, if aligned with community needs and marked by transparency, can empower people to lead clean environment initiatives and promote data-driven policy formulation towards building sustainable urban resilience.

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Abstract:
Air pollution has been a major problem in the world, and New York City is most definitely not excused from the impact. Air pollution has become a significant public health concern in the city, with residents reporting an increase in asthma cases and difficulty breathing. Our purpose is to combat air pollution by using community-based, low-cost air filtration and CO_2 monitoring. To do so, we created a low-cost air filtration and monitoring system. Using sodium hydroxide or activated carbon to reduce CO_2. Using such a system reduces air pollution in the targeted areas where the device is used. To track our progress, the device will have built-in air monitoring sensors and NDIR CO_2 sensors, which measure air pollution levels in real time.
Making it active and real to local residents; creating a more urgent need to combat this problem.
This system is not only rooted in the device but also in the community in low-income areas. Part of solving the air pollution crisis in New York City is to educate the residents living there. With workshops, flyers, online websites, and billboards, we can further help educate locals and actualize air pollution. This would result in major improvements in air quality and increase the public's health awareness, especially in marginalized low-income spaces of New York City. As well as help with local residents' health and reduce asthma cases in neighborhoods throughout the city. Overall, we can conclude that a CO_2 air filtration system is a great, low-cost start to combating air pollution in New York City. And with the ability to track air pollution levels, we can measure in real-time how this system is doing in combating air pollution. Therefore, with the low-cost helping marginalized communities breathe better, ensuring better air quality and health for New York City Locals, especially those in low-income marginalized communities.

INTRODUCTION:

Air pollution has become a major public health crisis in urban areas and has put certain low-income communities at a greater risk. In New York City, for example, children with asthma are more than five times more likely to suffer from the condition in areas like East Harlem, the South Bronx, and Yorkville (NYC Environmental & Health Data Portal, n.d.). Environmental pollutants such as carbon dioxide (CO_2), nitrogen dioxide (NO_2), particulate matter (PM2.5) from traffic, industry, and waste management practices are associated with respiratory health issues (South Bronx Unite, n.d.; IQAir, 2021).

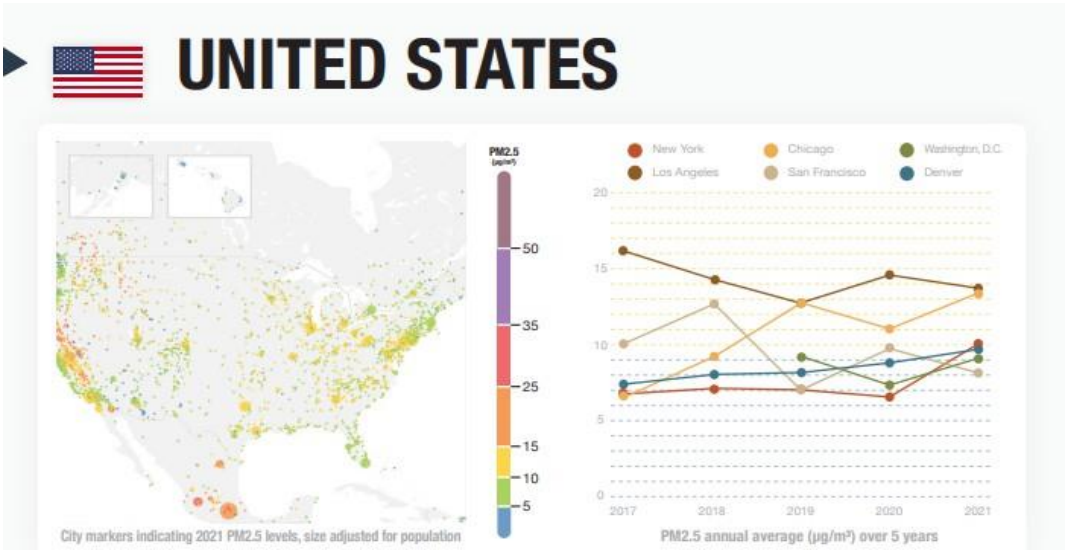

Figure. 1: Since the onset of the Industrial Revolution, air pollution has risen steadily

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particularly in urban centers such as New York, London, Los Angeles, Wuhan, and Rome. The overall increase in air pollution is attributable to many polluting sources, like emissions from industry, congestion from traffic, incineration of waste, and broader anthropogenic behaviors causing pollution. The role of indoor pollution is also an important consideration in the global statistics of air pollution activity, with many indoor pollutants often caused by cooking foods with inefficient fuels and contamination from a lack of ventilation. According to the World Health Organization, indoor pollution continues to be a significant contributor to premature deaths for millions around the globe. Urban populations face mounting risks of exacerbated respiratory illnesses including asthma from air pollution. For instance, in neighborhoods in New York City where the Bronx reveals some of the highest rates in the United States for childhood asthma hospitalizations (approaching five times that of the United States average). The outdoor pollutants those exposed to air pollution (both indoor and outdoor) may experience include air particulate matter (PM2.5) which is linked to inflammation, oxidative stress, and DNA damage. Numerous pollutants have emerged worse or equivalent in concentration in many cities in the U.S over the past five years, as illustrated by the figure presented in this paper. The atmospheric (air) concentration PM2.5 pollution trend were indicative of how the U.S. cities e.g., Los Angeles, Chicago, are consistently above safe levels of exposure. The modeled health impacts from indoor sources of air pollution as well as outdoor sources of air pollution represent a double-whammy of the burden of air pollution on public health, and need for equitable environmental interventions.

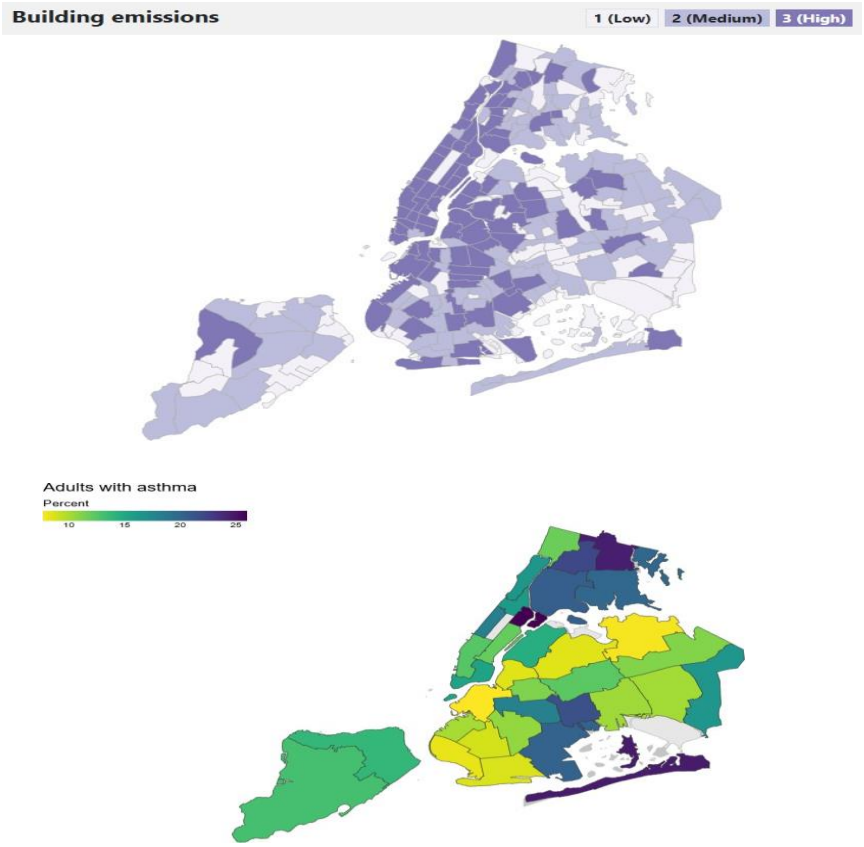

Figure 2. These maps illustrate the geographic relationship between building source air pollution and adult asthma prevalence across New York City neighborhoods. The left map depicts building emissions by neighborhood with 3 levels of building emissions (Low (1), Medium (2), and High (3)), with the dark purple color representing higher building emissions. The right map shows the percentage of adults diagnosed with asthma, from green (10%) to dark

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purple (25%) by the percentage of adults with asthma. An inspection of the maps reveals that there is a clear geographic association between neighborhoods with high building emissions and those with high asthma prevelance. For example, the maps clearly demonstrate areas such as the South Bronx, northern Manhattan, and portions of central Brooklyn are both dark in color suggesting that these neighborhoods have poor air quality from sources of localized pollution, and they have respiratory health disparity represented by the prevalence of asthma. Overall, these maps provide evidence to support the hypothesis that environmental exposure increased rates of chronic respiratory illnesses are associated with historically-excluded communities.

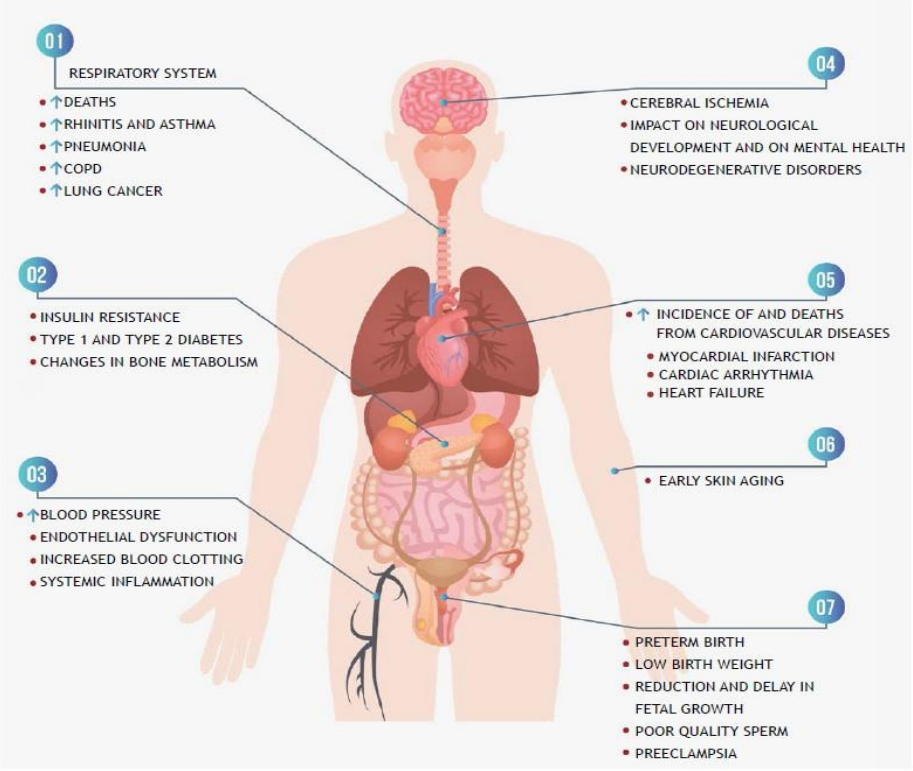

Figure 3. This figure illustrates the various physiological impacts of air pollution on many bodily systems. This figure summarizes the potential effects of air pollution, including, but not limited to, increased incidence of respiratory illnesses (e.g., asthma, chronic obstructive pulmonary disease [COPD], pneumonia, and lung cancer), insulin resistance/type 2 diabetes,

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cardiovascular diseases (e.g., heart failure, myocardial infarction), neurodevelopmental/cognition difficulties, reproductive problems, and possibly premature skin aging. There is potential for increased urgency of health consequences in the region: South Bronx, East Harlem, and Yorkville; where there is significant pollution and correspondingly high asthma numbers.

Hospitalization of children with asthma in the South Bronx is almost five times higher than the national average, while childhood asthma hospitalization rates in East Harlem and certain parts of Brooklyn are twice the citywide average. The incidence rate in metropolitan New York is a new childhood asthma case approximately every 25 minutes, averaging 21,000 new childhood asthma cases per year, driven by exposure to the environment. Populations of low-SES and a

high proportion of minorities who are disadvantaged have historically been inordinately affected by the impacts of environmental exposures; providing an acute environmental justice problem.

While there is urgency in addressing the relationships to pollution, the implementations

are not uniformly distributed. Technological mitigations addressing air filtration and real-time air pollution detectors are mostly unattainable for marginalized communities. Additionally, there's

little public awareness of natural, invisible environmental pollutants like elevated carbon dioxide (PMC, 2021). Limited access to the mitigation and knowledge of exposure creates cycles of injustice to disadvantaged communities, again by increased exposure and decreased access to the mitigation.

To tackle the problem, our work combines principles of environmental engineering and public health to create a compact, inexpensive air filtration and monitoring system. The device uses a chemical absorbent (either sodium hydroxide or activated carbon) to capture and reduce CO_2 in targeted parts of the space it captures. Furthermore, air quality, such as NDIR CO_2 sensors and air quality monitors, and any pollution levels, are tracked in real-time using integrated sensors, and essentially make the pollution visible or understandable for residents. These features not only deliver a technological solution to pollution but also take the passive exposure to air pollution and make it active. Residents can actively track what is happening, when it is happening, and if their area is in danger, empowering them to take action.

Importantly, our method is rooted in the community itself. We are additionally deploying these devices in high-risk neighborhoods, such as the South Bronx and East Harlem, with outreach to create a feedback loop including dashboards linked using QR codes, flyers, and educational

workshops. There is intent for pilot programs to provide residents with the opportunity to interact with the data, understand past trends in their environment, and provide feedback on their appraised effectiveness. Member feedback will be crucial in improving the device, but even more importantly, in creating local policy recommendations based on their lived experiences.

While our primary focus is on air quality improvement, we also aspire to make systemic change. We view this project as a starting point to create data-informed advocacy tools for

communities in environmental justice. Our hope is that access to credible, localized, mediated environmental data will empower neglected communities to influence zoning decisions, advocate for green infrastructure, and draw regulatory scrutiny towards their conditions. In the long term, partnerships with public health practitioners, urban planners, and emerging green technology

startups could expand the impact of this project into individualized real-time monitoring. Thus transforming a community-driven solution into a potential case study of how other cities and

communities can confront the structural inequity and disparities that have led to disenfranchisement in their own communities.

Our intention is to mitigate the cycles of injustice by developing a low-cost and community-centered air purifier, with a CO_2 monitor, as a starting tool. Our approach of revealing (and drawing attention to) the invisible pollutants allows families to have not only clean air but also the data to advocate for systemic change.

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LITERATURE REVIEW:

Despite decades of awareness, air pollution remains a persistent challenge worldwide that needs an urgent technological response to reduce its harm. Air pollution is a major contributor to noncommunicable disease and is responsible for almost 7 million deaths annually (World Health Organisation [WHO], 2025). Noncommunicable diseases(NCDs) affect multiple organs in the body, not just the lungs, like the kidneys, liver, and eyes. The WHO emphasizes that many of
these deaths are preventable through coordinated policy efforts with the energy, transportation, and agriculture sectors. However, the benefits of such efforts are often not felt equally across communities.

People in lower socioeconomic positions have higher air pollution exposure, both at work and at home. Low-wage jobs, such as construction, waste management, and industrial labor, often require large amounts of outdoor work. This places the workers in direct contact with
vehicle and industrial emissions as they work. At the same time, low-income neighborhoods are more likely to be located near highways, factories, and industrial zones, resulting in consistently poorer air quality in the places residents live. With industrial plants and transportation pollution placed near low-income neighborhoods, air pollution is high in places where they live. Hispanic communities in the United States are exposed to 63% more air pollution than they generate,

while white Americans experience less pollution than they produce(Environmental Health Perspectives, 2024) . These communities also often lack adequate health care, causing pollution-related conditions like asthma and heart disease to worsen over time. Therefore, the
hazardous working conditions, polluted living environments, and limited medical resources make air pollution a larger challenge for low-income groups (Nature Communication, 2023).

Although filtration technology exists to mitigate indoor air pollution, most current solutions fail to address the full range of pollutants found in high-risk environments.

High-Efficiency Particulate Air (HEPA) filters are designed to trap 99.97% of particles that are 0.3 micrometers in size. So it is highly efficient in removing solid particles such as dust, pollen, and certain bacteria. HEPA filters are widely used in various applications, due to its effectiveness, such as in air purifiers and HVAC, improving indoor air quality (U.S Environmental Protection Agency (EPA) 2024) However, HEPA filters alone cannot trap
gaseous pollutants such as ozone and carbon dioxide(CO_2), which is common in areas with high traffic and industrial activity. To effectively remove these gases, a carbon filter must also be used. As ozone and carbon dioxide(CO_2) increase in the air, the limitations of HEPA filters make them insufficient for the full range of pollutants found in low-income, high-risk urban neighborhoods. Our low-cost air filtration system is made to specifically target gaseous pollutants like CO_2, one of the most overlooked yet pervasive threats in these areas. This adds an essential layer of protection for communities that live and work near pollution sources.

Air pollution is a worsening national problem, with cities in California and New York receiving failing grades for ozone, short-term and year-round particle pollution(American Lung Association, 2023). As urbanization and climate change continue to accelerate, the ozone level and air toxicity are expected to increase sharply (U.S Environmental Protection Agency,2025). Warmer temperatures intensify ground-level ozone production, and an increase in industrial activity and traffic further contributes to the high concentration of carbon dioxide (CO_2), nitrogen dioxide (NO_2), and fine particulate matter (PM2.5). These pollutants are particularly dangerous for individuals with pre-existing health conditions and children, who may suffer long-term respiratory and cardiovascular damage. This growing threat intensifies the need for an effective and adaptable filtration system, especially in communities already burdened by environmental injustice. Traditional air purification solutions often fall short in high-pollution zones, and many do not adequately filter gaseous pollutants like CO_2 or ozone (ISO-Aire). As pollution becomes even more widespread, filtration technologies must evolve to be functional and accessible.

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While carbon-based filtration is capable of removing gaseous pollutants like ozone and carbon dioxide (CO_2), the systems that use them are often expensive and inaccessible to low-income households. High-quality air purifiers equipped with activated carbon filters can cost hundreds of dollars upfront, with replacement filters adding ongoing financial strain. In addition to their cost, most commercial filtration units are large, stationary devices designed for single-room use. This makes them impractical in large households and for use outside. (ORANSI,n.d) Because of these limitations, many of the communities most affected by air pollution are also the least likely to benefit from existing filtration technologies. Without a scalable, low-cost, and portable alternative, low-income residents are left vulnerable to long-term exposure and its associated health risks. Our device directly addresses this gap by using

affordable and compact activated carbon filtration, designed to be deployed in community spaces, apartments, or even outdoors Given the severe health consequences of air pollution, its disproportionate impact on low-income communities, and the limitations of existing air filtration technologies, there is a clear and urgent need for an affordable, effective, and community-centered solution. Our device fills this gap by offering a portable, low-cost air filtration system specifically designed to remove gaseous pollutants like carbon dioxide. By integrating real-time monitoring and community data access, it encourages residents to understand and advocate for their environment. As air quality challenges increase with urbanization and climate change, such innovations are essential to advancing environmental health equity and reducing the burden of pollution-related diseases in high-risk communities.

RESEARCH GAP:

Despite growing awareness of air pollution's health effects, inexpensive and accessible community-friendly solutions are scarce, particularly for low-income urban populations. Most air purification technologies are tailored for indoor, individual household use in higher-income settings and primarily rely on HEPA filters. While HEPA is effective at removing particulate matter, it does not remove gaseous pollutants like CO_2 or ozone, two of the chief culprits of poor air quality in highly trafficked and industrial areas. This technological deficit disproportionately burdens communities already bearing systemic environmental inequalities and added toxin exposure.

Few existing systems combine low-cost air filtration with local data monitoring and real-time public engagement. In addition, there is little research on solutions intended to reduce CO_2 levels in vulnerable communities, which suffer from poor air quality with immediate public health impacts. Our project bridges this gap by developing and deploying a low-cost, transportable air filtration and sensing system that not only addresses CO_2 but also involves community members through visible, accessible air quality information. By basing our solution on local context and community involvement, we aim to drive both health outcomes and systems change.

DATA ANALYSIS:

In order to ground our design in real-world needs, we conducted a survey by a convenience sample among residents and visitors of New York City, asking about perspectives on local air quality, as well as participants' understandings of impact on their own respiratory health. Of participants, 41.7% reported respiratory symptoms such as asthma, wheezing, and/or coughing, and many of the participants of the survey identified environmental triggers for these symptoms, including, primarily, poor ventilation, car pollution, and dust in the city.

When asked what borough had the worst air pollution in New York City, 58% identified Manhattan as the borough with the worst air, while responses from other boroughs tended to implicate areas with higher vehicle traffic. When participants were asked what contributes most to pollution in the city, 'vehicle traffic' was the most visible environmental trigger. On the topic of governmental support to reduce pollution in New York City, most participants expressed disappointment with how little visible action there was on the part of the government to reduce pollution in the city. It came through clearly in our survey data that there was a consistent link between individual perceptions of pollution and their lived experiences of respiratory health concern, which reinforced the relevance and urgency of our proposed intervention.

In light of these findings we developed a small, modular air filtration device, designed in Fusion 360 and awaiting operation testing via Ansys Computational Fluid Dynamics (CFD) software. The device has:

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- 3D printed or recycled plastic case
- Chemical absorbent chamber (NaOH, KOH, or activated carbon)
- Fan-aided air circulation system, or impeller
- NDIR CO2 sensors for real time ongoing assessment of environments
- Wireless data transmission
- Solar panel or rechargeable battery for power
- QR code display plate to connect to a public air quality tracking board

This system functions as a device for air purification and as an air pollution monitoring device that is transparent and offers the public alternative real-time access to pollution levels. We will perform controlled laboratory testing to access the effectiveness of the system, the main steps will include:

- Measuring CO_2 concentrations before and after filtration.
- Using several different absorbents and measuring their performance at a variety of environmental characteristics.
- Validating sensor performance and study of data transmission reliability.
- Our benchmarks for success will be:
- Greater than or equal to 80% consistent reduction in CO_2.
- Less than 5% error in sensor data in comparison to baseline standards.

After laboratory verification, we will roll out a pilot in three low-income, high-pollution neighborhoods in New York City: East Harlem, South Bronx, and Yorkville. In the course of 4–6 weeks, we will install 2–3 filtration units per site on existing urban infrastructure such as poles, buildings, or public kiosks.

Each unit will:

- Capture and record CO_2 pollution hourly
- Push live data to a public-facing web portal accessed by QR code
- Be supplemented by community outreach such as poster and flyer campaigns, and engagement sessions with those who live at each site to raise awareness and solicit feedback
  This will also serve as a test of public interaction with this technology, and common themes to refine design features based on lived experience and feedback from those locals who participate.It will be located in 3 low-income NYC neighborhoods with high pollution levels, for example: East Harlem, the South Bronx, and Upper East Side-Yorkville, and the duration will be 4-6 weeks of continuous operation

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CASE STUDY:

Throughout the past years, numerous technologies have been developed to combat the global air pollution crisis. For instance, DAC (direct air capture), this technology reduces CO2 emissions from the ambient air. Although the impact that was hoped to occur using this technology is rather optimistic for our situation with air pollution around the world. Researchers at the MIT Energy Initiative (MITEI) hope to continue to develop DAC so that when it's ready, it can be used to help with the energy transition. Researchers acknowledge that DAC is most definitely not the best technology used to combat CO2 emissions, as it high too expensive and does not reduce as much CO2. But they do acknowledge that it can be used later on to meet the net-zero emission cost. Another technology that is used to combat air pollution is DEC. DEC is used to measure outdoor air pollution in New York City. Then these measurements are reported to the EPA's Air Quality System (AQS) API. This system also provides current air quality measurement data and air quality forecast, while also providing which pollutants are most dangerous to human health at the moment. New York State also provides air quality alerts via DEC Delivers and other types of broadcasts. This technology is used across 50 US states and provides real-time reading measurements such as criteria pollutants (ozone (O3), sulfur dioxide (SO2), oxides of nitrogen (NOx), carbon monoxide (CO)), PM2.5 and PM 10 (fine particulate with diameter less than 2.5 or 10 microns), black carbon, ultrafine particle (UFP) count, meteorological data. Overall, there are many devices used to help with the air pollution crisis, and no matter how little of an impact they have, they all matter in combating air pollution.

The air pollution crisis not only impacts the environment it also impacts our health as adults, children, and seniors. The National Library of Science has a case study with asthma hospitalization in New York City. By 2030, more than 60% of the population will be living in urban areas. Already over 1 billion people were added to urban areas between 2000 and 2004. This creates a mixing pod of different environmental and socioeconomic factors that vary profoundly from neighborhood to neighborhood. Pulse (Participatory Urban Living for Sustainable Environments) is an international project that researches and collects data on the health of people in different environments. Using a spatial clustering method and considering the rate of asthma hospitalizations and the yearly PM2.5 concentration, which showed some interesting details. Details as stated:

- In 7 out of 10 clusters found by the algorithm, an occurrence of low PM2.5 concentration corresponds to a low hospitalization rate and vice versa;
- 3 out of 10 clusters, all within the borough of Manhattan, are in contrast with this tendency, since they present the highest PM2.5 levels together with the lowest hospitalization rates of all the city
- The Bronx, East Harlem and some neighborhoods in North/Central Brooklyn close to some of the biggest highways of the city (e.g., Brooklyn-Queens Expressway, Long Island Expressway) have the highest hospitalization rates of the whole city, together with the highest pollution level of all the neighborhoods excluding the wealthiest areas of Manhattan.

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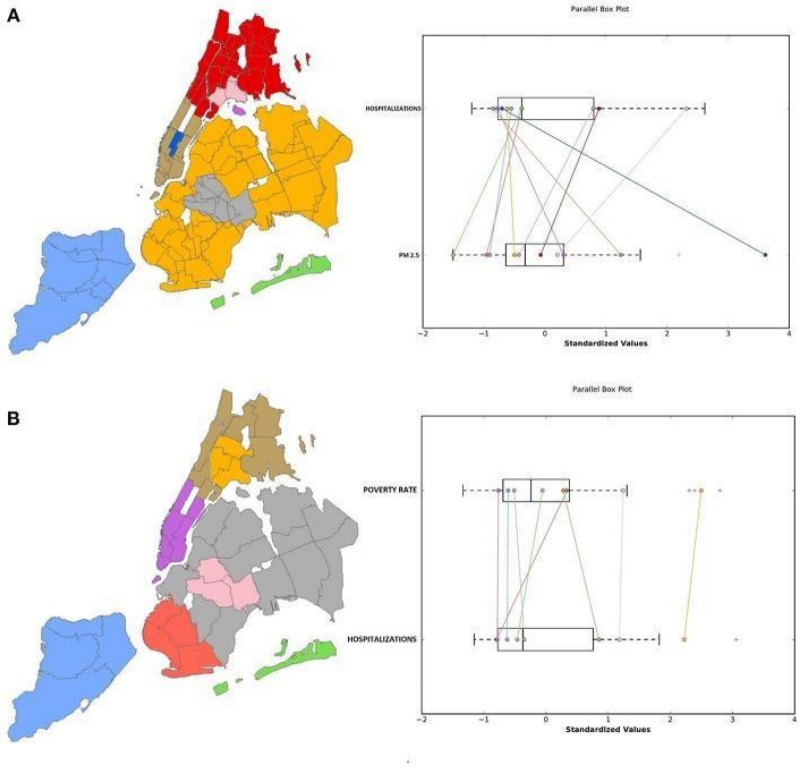

Figure 3. Results of the spatial clustering considering (A) the average 2014 PM2.5 concentration and the asthma hospitalization rate, and (B) the poverty rate. On the left, a color-coded map of the clusters and on the right a parallel box plot that shows the relation between the parameters' distributions.

This shows that socioeconomic factors also play a role in the high asthma hospitalization rate, not only air pollution. Which is why it's important to educate marginalized communities. In the end, while air pollution should be combated, we should also strive to educate low-income communities, as socioeconomic backgrounds can also affect health.

CONCLUSION:

Air pollution isn't just an environmental concern; it's a crisis that involves public health, equity, and justice. In cities like New York, where vulnerable populations face disproportionate exposure to harmful pollutants such as carbon dioxide, particulate matter, and nitrogen dioxide, the consequences of inaction are real and far-reaching. Our initiative responds to this critical challenge by developing an affordable, modular air filtration and monitoring system specifically tailored for neighborhoods that need it most. Through public dashboards, QR code accessibility, and community feedback mechanisms, we aim to turn hidden dangers into clear, understandable data and shift passive exposure into proactive engagement.

This approach empowers residents to protect themselves from immediate health threats and encourages them to push for long-term policy changes based on real evidence and personal experiences. This project goes beyond just a technical solution; it's about promoting environmental justice. By empowering communities to measure and understand the air quality they experience, we set out to tackle the deep-rooted inequalities that have contributed to urban pollution. Our goal is to create a model that other cities can follow in their efforts to address these issues.

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