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Article

Artificial Intelligence-Based Smart Solution to Reduce Respiratory Problems Caused by Air Pollution

Jyoti Bhardwaj[1]*, Pawan Sharma[2]
[1]Acton-Boxborough Regional High School, Acton, MA, USA
[2]Center for Translational Medicine, Division of Pulmonary, Allergy and Critical Care Medicine, Jane & Leonard Korman Respiratory Institute, Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, PA, USA

SUMMARY

Globally, air pollution is a significant concern for human health. Artificial sources of particulate matter (fine dust particles suspended in the air), especially $PM_{2.5}$, are the significant constituents in indoor air pollution and prominently leads to many lung-related illnesses. Research suggests that around 90% of people spend ~22 hours inside every day, either at a home, office, factory, or restaurant. Plants act as a natural detoxifying agent by taking particulate matter (PM) waste from the atmosphere. Our hypothesis tested whether placing specific plants indoors can reduce levels of PM inside by using principles of biomedical engineering and machine-learning approaches. Our data showed that plants improved the overall quality of the air in the room. Levels of $PM_{2.5}$ were decreased dramatically in the rooms compared to the average levels measured outside the house. As higher PM exposure in humans is associated with many diseases, our research suggests that plant-based interventions coupled with a sensor and cloud-based application using artificial intelligence may be useful in the long run to reduce indoor air pollution.

INTRODUCTION

Air pollution is a global issue that has been affecting the world for years, and it is one of the leading causes of death. The World Health Organization (WHO) estimates that 4.2 million people die each year due to diseases caused by air pollution, such as heart diseases and strokes (1). A significant portion of air pollution is the particulate matter (PM) which is a fine dust particle suspended in the air. Specifically, large amounts of $PM_{2.5}$ and PM_{10} are from human-made sources like emissions of combustion of gasoline, and they are significant constituents of the ambient air. A healthy amount of $PM_{2.5}$ is <50 μg/m³, and anything >150 μg/m³ is unhealthy and borderline hazardous (2). There are also other hazardous compounds in the air, such as SO_2, CO_2, and NO_2 gas (3). A significant issue is that air pollution is going to increase. In the last five years, the PM levels have risen about 5.5% only in the United States (3).

Furthermore, the high air pollution leads to lung-related illnesses such as asthma, chronic obstructive pulmonary disease (COPD), and many forms of lung cancer (4). According to a study conducted on the effects of air pollution on the lungs, 9 out of 10 people exposed to polluted air reported having COPD (5, 6). Air pollution primarily affects the respiratory system, as well as the cardiovascular system and other organs (7). Air pollution is prominent all over the world, and countries that are most significantly affected by air pollution are in Southeast Asia, specifically China and India (8). The average level of $PM_{2.5}$ in these countries for 2019 was well above 60 μg. Significant contributors to these hazardous levels of PM are automobile emissions, chemicals from factories, fine-dust, perfumes, cigarette smoke, building materials, and cleaning products. About 7 million people die prematurely due to air pollution every year (1). Now it is also emerging that air pollution is linked with higher COVID-19 death rates, according to the first study to look at the link between long-term exposure to $PM_{2.5}$ generated largely from fuel combustion from cars, refineries, and power plants and the risk of death from COVID-19 in the United States (9).

Although outdoor air pollution has many harmful effects, indoor air pollution is a significant cause for concern as well. The levels of air pollution and PM inside buildings and homes are relatively similar to the levels of PM outside. The majority of people spend their time inside (~22 h) each day; therefore, they have a likelihood of being affected by the repercussions caused by indoor air pollution (9). Approaches like active real-time monitoring of PM may help to reduce it and eventually prevent the development of airway diseases. Human-made sources of PM, especially $PM_{2.5}$, are important constituents and an indicator of air pollution in any given location. Plants act as a natural detoxifying agent by taking PM waste from the atmosphere. Plants have been shown to reduce the waste of the atmosphere and therefore, may assist in preventing the development of severe lung illnesses (10). Therefore, our experimental design tested whether placing specific plants indoors could reduce PM inside the house, which we hypothesized they would. These results might suggest reducing the risk of lung-related illnesses through the principles of biomedical engineering and machine learning approaches.

RESULTS

The testing sites were located in two highly-polluted cities in India—Agra, Uttar Pradesh and Gwalior, Madhya

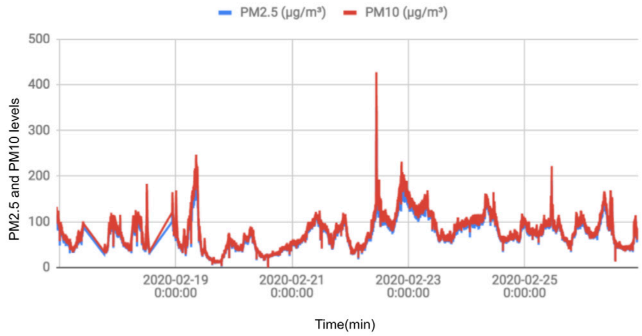

Figure 1: Levels of $PM_{2.5}$ and PM10 (µg/m³) in the tested home in Gwalior over a one-week period. Data points of the $PM_{2.5}$ and PM_{10} taken in at 1 min intervals. The levels of $PM_{2.5}$ are shown by the blue

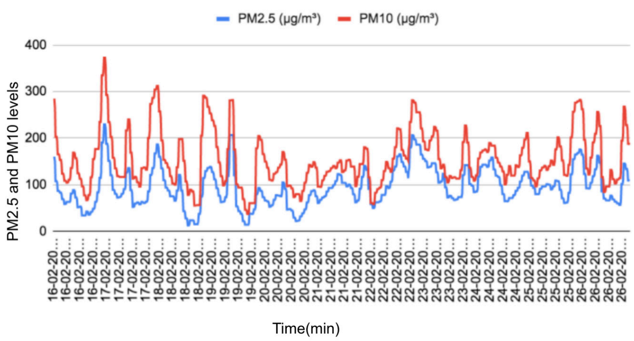

Figure 2: The $PM_{2.5}$ and the PM10 (µg/m³) levels outside Gwalior taken over a one-week period. Data points of $PM_{2.5}$ and PM_{10} taken in at 15-min intervals. The levels of $PM_{2.5}$ are shown by the blue line and the levels of PM_{10} are shown with the red line.

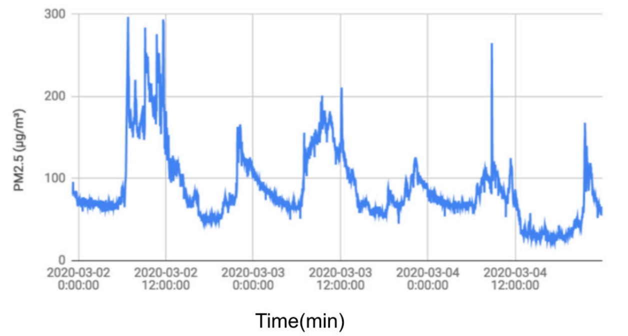

Figure 3: The levels of $PM_{2.5}$ (µg/m³) in the tested home in Agra taken over a one-week period. Data points recorded over one-minute intervals. The levels of $PM_{2.5}$ are shown by the blue line.

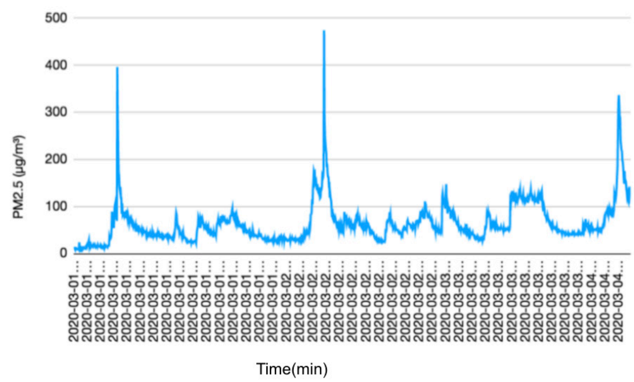

Figure 4: The data $PM_{2.5}$ (µg/m³) outside in Agra over a one-week period. Data points recorded in 15-min intervals. The levels of $PM_{2.5}$ are shown by the blue line.

Pradesh. Real-time data was recorded using a sensor placed in a room within a home in these cities that transmitted data, PM levels and other air pollution related parameters to the cloud interface every minute. Baseline data was collected by comparing the particulate matter levels indoors to those levels outdoors. The data was collected for a continuous seven days and averaged to be compared with other values.

$PM_{2.5}$ and PM_{10} were the more prominent species of air pollution detected in Gwalior; therefore, they were compared to the outdoor values. $PM_{2.5}$ and PM_{10} are in a similar range (50-400 µg) inside and outside the house (**Figures 1,2**). The level of $PM_{2.5}$ was >50 µg/m^3, which is unhealthy for the lungs. $PM_{2.5}$ was the most prominent species of air pollution detected in Agra; therefore, it was compared to the outdoor value. The data shows that the levels of $PM_{2.5}$ inside were the same as the levels outside the house (**Figures 3,4**). Sometimes the values inside may be higher than outside due to PM emanated from household activities like cooking and sprays.

Both the baseline data showed that the levels of $PM_{2.5}$ and PM_{10} are the same inside and outside the house. For most of this testing, the level of $PM_{2.5}$ was >50 µg/m^{3,} which is unhealthy for the lungs. After recording the baseline data for 7 days, selected plants were introduced into the houses for a given period (2 weeks) as an intervention. These data were analyzed by comparing the outdoor $PM_{2.5}$ to the levels inside.

In Gwalior, the levels of $PM_{2.5}$ with plants kept indoors decreased 46.47% when compared to the outside PM values (**Figures 5,6**). The levels of PM_{10} were reduced by 122.37% with plant intervention compared to the outside values. Similarly, in Agra (**Figures 8,9**), levels of $PM_{2.5}$ were reduced by 31.15% with plants kept in the home, compared to the outside levels.

DISCUSSION

It is believed that in the 21st century air pollution will be the leading cause of human disability and death of 9 out of 10 people who will breathe air containing high levels of pollutants (5, 6). PM are fine dust particles that are easily transferable into indoor buildings. The easy transferability is why the levels of PM indoors is the same as outdoor levels, and sometimes the PM level indoors is higher than the outdoor levels due to PM created by household activities such as cooking and sprays. Indoor air pollution is the primary cause of lung-related illnesses, as 90% of people spend about 22 h each day indoors (9). We measured both indoor and outdoor PM levels and used a plant-based intervention to reduce indoor

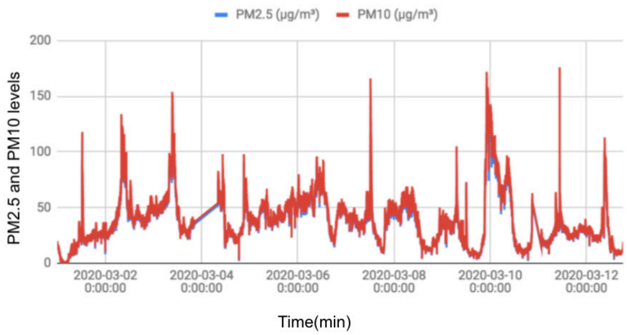

Figure 5: The levels of $PM_{2.5}$ and the PM_{10} (µg/m³) in the tested home in Gwalior after the plants were added in the room. The testing period was two weeks and the data points were collected over one-minute

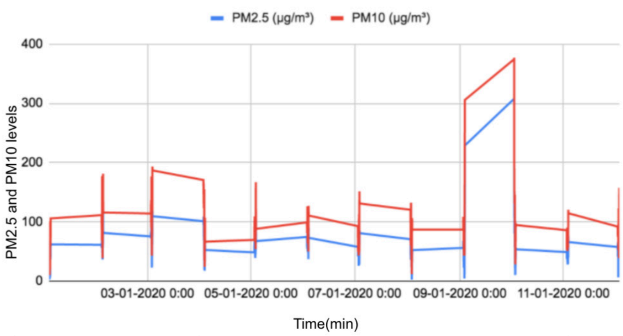

Figure 6: The $PM_{2.5}$ and the PM_{10} (µg/m³) levels outside in Gwalior. The testing period was two weeks and the data points were collected over 15-minute intervals. The levels of $PM_{2.5}$ are shown by the blue line and the levels of PM_{10} are shown with the red line.

PM by actively monitoring using a sensor. We then used an AI-based approach to analyze these data. These results suggest that our simple approach can be further refined to engineer a more complex PM sensing and monitoring system that can enable us to utilize these emerging technologies to reduce the burden of air pollution, ultimately promoting better lung health.

The baseline data from both cities showed that the $PM_{2.5}$ and PM_{10} levels in the houses were similar to the outside levels, suggesting that staying indoors may not be a good option in places that are highly polluted. In both Agra and Gwalior, $PM_{2.5}$ and PM_{10} were >50 µg/m³, which is unhealthy for the lungs. Highly polluted areas contain unhealthy and potentially hazardous amounts of PM in the ambient air. Sometimes, the indoor PM levels were higher than the outdoor levels due to indoor household activities, making it unsafe to stay indoors for long durations of time (3). Plants act as a detoxifying agent in nature (10). In our experiment, after the intervention of plants, $PM_{2.5}$ and PM_{10} decreased indoors, compared to the outside $PM_{2.5}$ and PM_{10} values in both the cities. There was a decrease of 46.47% in the $PM_{2.5}$ levels for Gwalior and a 31.15% reduction in Agra. The reduction in particulate matter showed a positive correlation with air quality indoors. With the reduction in PM, people will

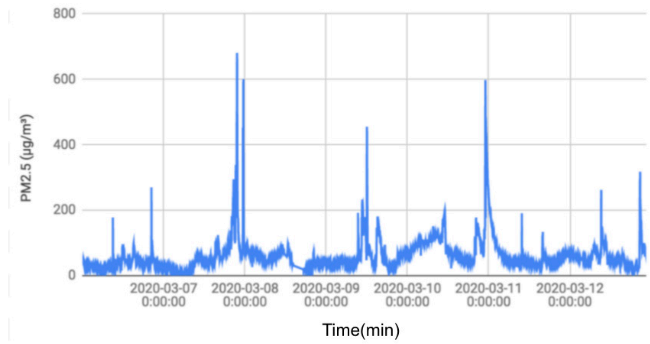

Figure 7: The levels of $PM_{2.5}$ (µg/m³) in the tested home in Agra with plants inside. The testing period was two weeks and the data points were collected over one-minute intervals. The levels of $PM_{2.5}$

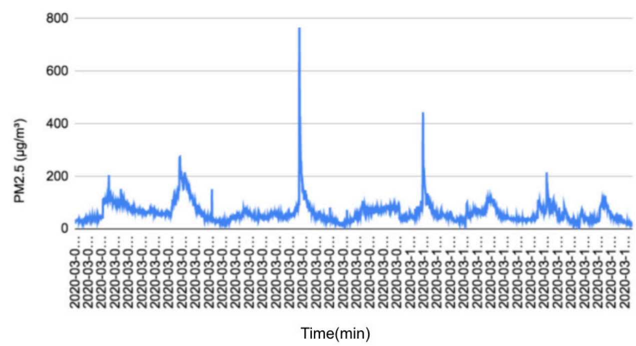

Figure 8: The data $PM_{2.5}$ (µg/m³) outside in Agra. The testing period was two weeks and the data points were collected over 15-minute intervals. The levels of $PM_{2.5}$ are shown by the blue line.

be exposed to less PM indoors compared to outdoors, which should mean better lung health over a period of time.

The differences in the percentages of reduction for both Agra (31.15%) and Gwalior (47.47%) may be due to confounding variables. The data for each of the locations were collected during different dates. A plausible reason for why there was a larger reduction in Gwalior is because the plants were intervened during the time where many places were closing down due to the COVID-19 virus. Due to the shutdown, the outdoor particulate matter resulting from gasoline combustion was limited.

We understand that there are limitations with real-time data collection, such as levels of PM possibly increasing with the sensor being too close to the kitchen or activities like smoking or vaping indoors. We reduced these variables by specifically placing the sensor in the bedrooms, which are away from the kitchen—a major source of indoor PM—and asking the resident to avoid smoking and using sprays/deodorants near the sensor for the duration of the study, both during the baseline and the intervention collections. Additional considerations for our study were to keep the same number of plants in the room and normalize data to square-feet space. Since a significant amount of PM in the houses is from outside, the decrease of particulate matter shows that the plants positively influenced air quality of the home. The lower levels of $PM_{2.5}$ and PM_{10} might show long term improvement in residents' health conditions.

Looking into the long-term impact of the plants in other highly-polluted cities, including the United States, would show if the reduction in indoor PM level correlates with beneficial health effects in humans. In the future, with artificial intelligence principles and machine learning approaches, we may be able to introduce automation to calculate how many plants will be required per square feet, calculate amount of water and nutrients required by the plant calculate amount of water and nutrients required by the plant, and introduce sensors that can monitor other gases (i.e., SO_2, CO_2, CO).

MATERIALS AND METHODS

Testing Locations

The testing locations were houses located in Gwalior and Agra, India, which are highly-polluted cities and the average $PM_{2.5}$ levels are >100μg. Due to the poor air quality of these cities in India, the indoor air quality can be impacted significantly.

Equipment

The Laser Egg device (Model 1, Kaiterra, USA), which detects $PM_{2.5}$ and PM_{10} in a given location, was used to collect the air quality data. This device was able to collect data on the air quality every minute and send it to the cloud. The fast responses and effective monitoring of the air quality made it efficient to compare indoor and outdoor data.

Recording/Measurement

The experiment design collected the baseline $PM_{2.5}$ and PM_{10} data for 3-6 days. The baseline was collected to compare the original air quality in the room to the outdoor air quality. The measurement of the $PM_{2.5}$ and PM_{10} was taken in micrograms. Afterward, there was an intervention of specific plants in the rooms of these houses. The $PM_{2.5}$ and the PM_{10} were collected for 1-2 weeks. The plants that were introduced in the experiment were common house plants such as the spider plant (chlorophytum). About two to three house plants were spread in the room depending on the size of the room. The Laser Egg device was placed relatively equidistant (3-5m) from each of the plants.

Data Analysis/Statistical Analysis

Once the data was in the cloud it was cleaned using Jupyter Notebook for indoor and outdoor data. The data was cleaned by removing missing data from the data sets. Graphs were generated using GoogleSheets to examine the data visually. Then we used a classification model to find the percent reduction of the particulate matter. The data was averaged using the model to help determine the relative average value of the particulate matter indoors and outdoors.

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