The Impact of Air Quality on Students Academics, Motivation and Mental Health

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Abstract

Poor air quality is a serious global issue, affecting all of the human population. The sources and mechanisms by which pollutants contribute to poor air quality are well documented, as are the associated deleterious health impacts. This paper focuses on a public health aspect of air quality science, asking how air quality affects students' academics, motivation, and mental health – as it will review current learnings within these specific fields as well as an investigated and analyzed experiment to expand on these findings. Many sources and studies concluded that poor air quality is associated with lower academic success, and degrades mental health in students and adolescents. This paper considers the academic performance, mental health, and motivation of students who may be exposed to poor air quality. These areas are evaluated using a self-assessment questionnaire. The questionnaire is directed toward teenage students from various environments and geographical locations, to assess if outdoor air quality affects high school-age students' academics, motivation, and mental health. The main objective of this study was to answer the following question: How does outdoor air quality affect students' academics, motivation, and mental health? A hypothesis suggests that with better air quality, students would be more productive and motivated to score higher on exams and also show better mental health quality. The results of the experiment were documented and statistically analyzed to draw conclusions based on the collected dataset of responses from the questionnaire. An interpretation of the results followed to find correlations between air quality and students' academics and their mental well-being. The study results indicated that in areas of poor air quality, students' were relatively unproductive, demotivated, and experienced weaker mental health in terms of restlessness, stress, anxiety, and depression.

Key Words: academic performance, air quality, Air Quality Index (AQI), particulate matter, PM 2.5, pollutants

Introduction

Air pollution poses significant risks to various demographics within society, as specific groups of people, such as the elderly, children, and those with chronic illnesses are more susceptible to the effects of pollution. More than 100 million people live in areas with air pollution exceeding the health-based air quality standards in the United States (Nolte, 2018). According to environmentalist Richard Fuller, even though UN agencies, and national governments are taking steps to solve this issue, little progress has been shown, especially in low-income countries with high levels of pollution (Fuller, 2022).

Air pollution is derived from both natural sources, such as wildfires and volcanoes, and human-generated sources, like smoke, ash, and gasses derived from the combustion of fossil fuels. (National Institute of Environmental Health Sciences, 2023). The United States Environmental Protection Agency (EPA) emphasizes the six common air pollutants: ground-level ozone, particulate matter, carbon monoxide, lead, sulfur dioxide, and nitrogen dioxide (Environmental Protection Agency, 2023). These air pollutants are proven to deteriorate respiratory health and are associated with oxidative stress and inflammation in human cells, leading to chronic diseases and cancer. Health concerns include cancer, cardiovascular and respiratory diseases, diabetes, obesity, and reproductive, neurological, and immune system disorders (National Institute of Environmental Health Sciences, 2023).

The vast majority of the published literature on air pollution has focused on covering the effects of poor air quality on students' academic performance and their mental health. For example, after conducting a survey-based study, researchers from the National Library of Medicine reported that ambient air pollution is linked with reduced Math and English Language Arts test scores among students (Lu, 2021). This study expands on and emphasizes how exposure to 12-month ambient air pollution levels is associated with neuroinflammation, neurodegeneration, and cognitive decline in terms of the students' attentiveness, and memory, especially in developing and growing children. Black carbon is a material released from gasses and burning fossil fuels, which makes up a large part of the particulate matter air pollutant (Environmental Protection Agency, 2011). The American Journal of Epidemiology discusses a study and concludes that kids experiencing certain levels of black carbon scored worse on memory and IQ assessments (Weir, 2012).

Additionally, a Cambridge study exploring the effects of air quality on mental health focuses on major effects on adults such as depression, anxiety, personality disorders, and schizophrenia caused by exposure to outdoor air pollutants (Kamaldeep, et al.). The paper also included that in a study of 2063 adolescents, psychotic experiences were common for those exposed to the highest levels of pollutants such as PM2.5 and nitrogen dioxide. Among adults, there was an evident association between long-term exposure to PM2.5 and depression, bipolar disorder, or suicide.

Furthermore, the significance of this topic caught the attention of a group of Japanese researchers, who focused on studying the effect of air pollution on individual students' motivation and productivity (Kameda, n.d.). Their research incorporated a controlled experiment to gather and analyze relevant data regarding each student's motivation levels in a classroom with correlation to the air in their environment. At the end of their study, researchers concluded that in an environment with poor air, students' motivation and learning desires decreased widely as well as their performance. The motivation for learning in a ventilated environment was higher by 3.7 - 11.7 percent than in a classroom with poor air quality.

Existing literature suggests that there is a strong correlation between air quality, student mental health, and academic performance. However, there is a limited amount of research that investigates the relationship between outdoor air quality and its effects on students' motivation and each individual's desire for productivity. This study aims to address this gap. By measuring air quality from public air monitors and simultaneously asking middle and high school-aged students throughout the United States about their academics, motivation, and mental health, this study hoped to test the hypothesis: with better air quality, students are more productive and motivated and have better mental health.

The primary metric of air quality used in this study was particulate matter, specifically PM2.5 – small particles in air that are 2.5 micrometers in diameter or less. PM 2.5 is a heterogeneous mixture that can include organic chemicals like sulfates, nitrates, or carbon; dust; soot; and metals. These particles can come from automobile exhaust, factory processes, wood burning, and other activities (Manisalidis, 2020). Unlike other air pollutants like ozone, particulate matter can be either directly emitted or can form within the atmosphere as a result of chemical reactions between pollutants. PM2.5 is easily affected by weather conditions like temperature, humidity, wind speed, and rainfall, with direct relation to climate change (Nolte, 2018). According to the EPA, PM 2.5 is used as a crucial indicator of air quality because smaller particles can enter the lungs and the bloodstream (Environmental Protection Agency, 2024). Fine particle pollution has been shown to cause many serious health effects, including heart and lung disease. Exposure to PM2.5 contributes to thousands of deaths every year. Children, the elderly, and people suffering from heart or lung disease, asthma, or chronic illness are most sensitive to the effects of PM2.5 exposure (California Air Resources Board, n.d.).

This paper consists of a synthesis of prior research and an original experiment to investigate the major effects of poor air quality on a few aspects of students' lives such as their day-to-day academic successes, mental health, as well as their daily drive for productivity.

Methodology

This study began with researching and gaining background content about some ways of how air quality affects aspects of students' lives. Research material was gathered from Google Scholar articles and government organization websites, utilizing keywords such as 'academic performance,' 'air quality,' 'particulate matter,' 'pollutants,' and 'PM2.5.'

The research study was conducted through an anonymized online Google form questionnaire to investigate the impact of poor air quality on students' academics, motivation, and mental health. The survey targeted high school students aged 12 to 20, encompassing diverse gender and age groups. The survey was sent to about 30 students around the United States to ensure variated and comprehensive data. The questionnaire comprised three sections: consent confirmation, participant background, and self-analysis. The consent section required participants to read an overview of the study and provide a mandatory signature to confirm their participation in the experiment. Following this, students supplied some background details such as age and gender before proceeding to the self-analysis section. Through the self-analysis, participants were asked to analyze their academics during a specific day, involving their motivation, productivity, and school successes in exams and assessments. They were asked questions about how academically stimulated they were during the day and if the air environment affected their motivation. Additionally, the participants were asked to reflect on their mental health based on aspects such as restlessness, stress, anxiousness, and depression. A copy of the consent form and Google form questionnaire can be found in the supplemental information section. An Internal review board approved of the study: consent and participant identity were adhered to throughout this study.

Air Quality Index (AQI) is divided into six categories corresponding to different levels of health effects (AirNow, n.d.). These AQI index ranges were used during the analysis of data for the study.

AQI	Level of Concern
201 - 300	Very Unhealthy
151 - 200	Unhealthy
101 - 150	Unhealthy for Sensitive people
51 - 100	Moderate
0 - 50	Good

Air Quality Index (AQI) values from PurpleAir Monitors were utilized to correlate with participants' responses based on the survey date. Various AQI monitoring platforms like AirNow, World's Air Pollution: Real Time AQI, and Purple Air were analyzed based on meeting specific criteria such as geographical coverage, real-time data availability and ease of data access. The selected AQI monitor must have widespread, accurate geographical coverage to ensure sensors are located near each participant. PurpleAir stood out as the most easily accessible monitor, providing accurate real-time data, making it the preferred choice over the other AQI data gathering platforms. PurpleAir sensors use reflections to count particles considering their sizes and conclude the types of particles present. PurpleAir particulate matter (PM) sensors are used in many countries by a variety of individuals and organizations for the continuous monitoring of ambient air pollutant conditions. The PurpleAir website displays a real-time map of the air quality all over the world. The map has capabilities to display the variations of air pollutants like particle matter (PM2.5, PM10), and ozone in the air (PurpleAir, n.d.). For this specific study, the PurpleAir PM2.5 AQI values were used because the large number of sensors around the world increased the chances of an available sensor located near each participant. Based on the student's location, a sensor was selected within the city and its data was downloaded as a CSV file. The file consisted of AQI values for the past 3 months at six-hour intervals. The average of four data points was considered, representing the AQI throughout the specific day that each participant filled out the questionnaire.

Upon data collection, responses were organized on a Google Sheet to establish correlations between participants' inputs and variations in AQI levels. Motivation, mental health, and productivity variables were segregated into different sub-sheets alongside corresponding AQI values. The independent variable was Air Quality, AQI, whereas the dependent variable was the students' academic performance, motivation level, and mental health. Meticulous outreach was conducted over four weeks, involving contacts around the United States and email communication with schools.

The gathered data was then processed to generate graphs using Python libraries: Matplotlib, Pandas, and NumPy. Visualizations, including bar, pie, and line graphs, facilitated the formulation of conclusive observations regarding the study's objectives. The trends were then analyzed using statistical tests, like the t-test. The utilization of these advanced statistical tools enhanced the robustness and reliability of the study's findings.

Results and Discussion

Table 1
Demographics of the Study Population

	Age (in years)		
	Female (N=15)	Male (N=11)	Total (N=26)
Below 12	2	2	4
12 - 14	6	3	9
15 - 17	6	2	8
18 - 20	0	1	1
Above 20	1	3	4
	(57.7%) [a]	(42.3%)	
	Location in United States [b]		
	Female (N=15)	Male (N=9)	Total (N=24)
Western states	9	5	14
Central and Midwest states	3	3	6
Eastern states	3	1	4

Note. From the questionnaire, 26 students completed the survey over a span of four weeks, from November 27 to December 25, 2023. Participant background statistics are presented in Table 1. The data showed that two students didn't include their location, therefore they were disregarded as a part of the study. Only 24 participant responses were used in the parts of the studies analysis using locations. Analysis of results emphasized the potential effects that short-term exposure to particulate matter has on students' academic performance, motivation and mental health separately.

[a] 57.7% were female, while 42.3% of the participants were males: 15 females and 11 males. The majority of the participants were in the age range 12 to 17, whereas the least number of participants were between ages 18 to 20. The mean age was 15 years old. [b] Additionally, 14 students were from Western states, 6 from Central or Midwest, and 4 participated from Eastern states.

Figure 1 illustrates the correlation between participant's average air quality and their indicated productivity levels on a 1 to 5 scale (1: least productive; 5: most productive). The average air quality for participants who responded as feeling the least productive (Level 1) during the day was 104, while the average air quality for participants who responded as feeling the most productive (Level 5) was 52. Two participants responded feeling Level 1 productivity, one responded with Level 2 productivity, Six responded, feeling Level 3 productivity, eleven participants responded, feeling Level 4 productivity, and four participants responded as feeling Level 5 productivity during the day of survey completion.

This analysis aimed to understand the correlation between the productivity levels and the outdoor Air Quality Index (AQI) measures. Data was divided into two groups: Group One (Levels 1-3) for lower productivity and Group Two (Levels 4-5) for higher productivity. Group One had 9 students with a mean AQI of 81.45, while Group Two had 15 students with a mean AQI of 60.0. An independent sample t-test (t-statistic = 2.2, df = 22, p = 0.04) revealed a significant difference between the groups, indicating that students with lower productivity levels had a higher mean AQI than those with higher productivity.

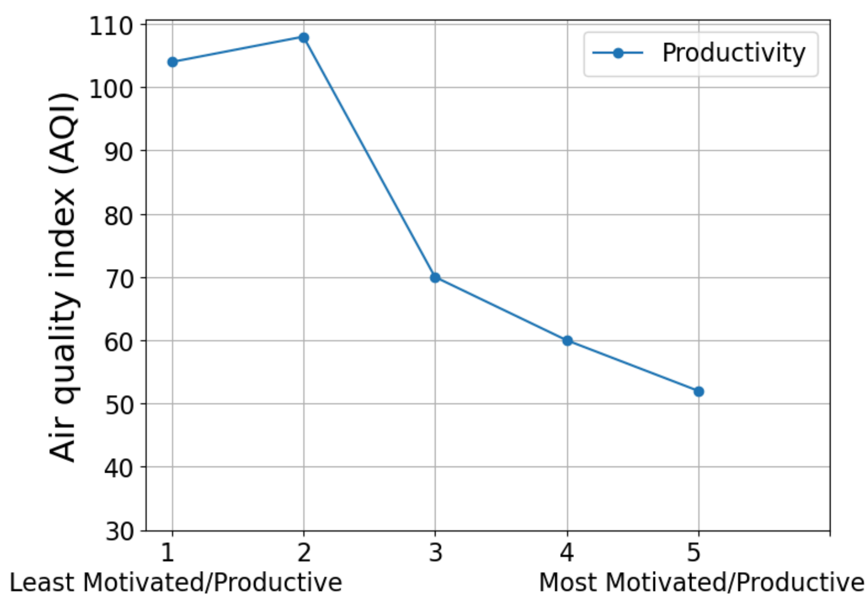

Figure 1: Productivity Levels vs. AQI

Figure 2 shows the correlation between the average air quality during two days for each participant indicating a specific level of motivation on a 1-5 scale (1: least motivated; 5: most motivated. The questionnaire asked for participants' ratings of motivation on the day of filling out the survey and the day prior, to prove or disprove a potential correlation. The average air quality for participants feeling least motivated (1) was 97, whereas the average air quality for participants feeling the most motivated (5) on the day they filled out the questionnaire was 53. The average air quality, the day before filling out the survey, for participants feeling least motivated (1) was 98, but 37 for most motivated (5) students. Figure 2 shows a negative correlation between Motivation and AQI levels, for both days. It can be concluded that with poor air quality, students feel less motivation, but with healthy air quality, students are more motivated throughout the day.

The main purpose of this survey was to analyze the relationship between students' motivation and the AQI levels. Data from the questionnaire response of rating motivation on a 1-5 scale was grouped into two categories to conduct a t-test. Group 1 consisted of AQI values corresponding to participants responding with levels 1 - 3 motivation. Group 2 consisted of the values corresponding to participants with motivation levels, 4 - 5. Group 1 consisted of 11 participants, with a mean AQI of 77.7. Group 2 consisted of 13 students and the mean AQI was 61.0. An independent sample t-test was conducted, comparing the means of both groups. The t-statistic for the test was 2.2, df = 22, with a p-value of 0.03 ($p < 0.05$). This test suggested a significant relationship between the mean values of both Groups. Group 1 (lower motivation levels) had a larger mean value of AQI measures than Group 2.

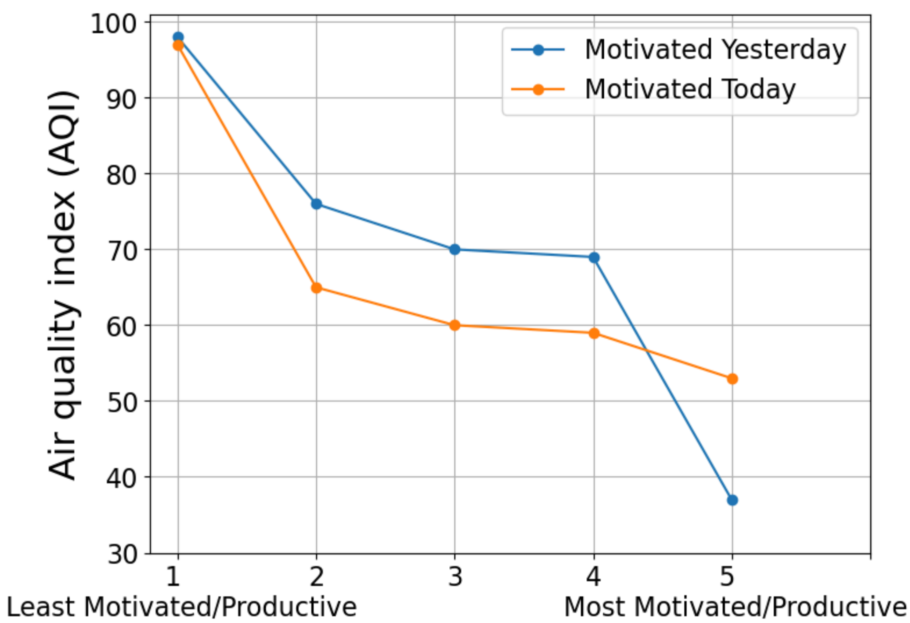

Figure 2: Motivation Levels vs. AQI

Figure 3 presents students' self-reflection regarding their mental health during the day, corresponding to the average AQI. These self-reflection questions were required to find a correlation between mental health and AQI. A total of seven participants from the survey responded on a day with less than 50 AQI, 14 were located in an area with AQI levels between 51 and 100, while 3 experienced above 100 AQI. All of the students living in an area with healthy AQI levels below 50 responded with ‘never’ or ‘sometimes’ feeling restless and depressed. Six out of seven students who had AQI below 50 responded with ‘never’ or ‘sometimes’ feeling stressed and anxious. All participants living with AQI levels above 100 responded with ‘always’ for feeling anxious and stressed. These results indicate that students exposed to lower AQI levels (less than 50, or 51 - 100) during the day are more likely to maintain better mental health quality in terms of feeling restless, stressed, anxious, and depressed. The participants who were experiencing higher AQI (above 100), tended to show lower mental health quality.

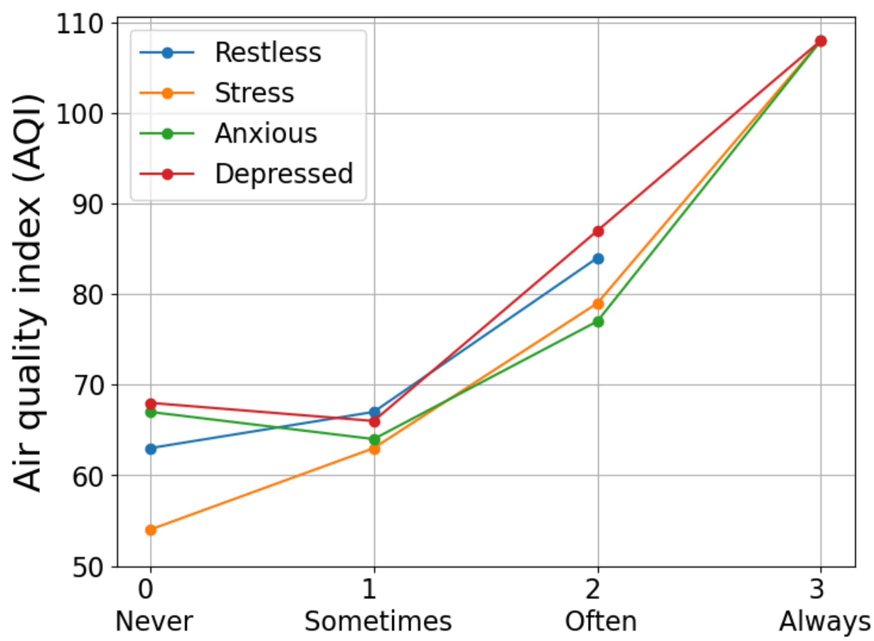

Figure 3: Participants Mental Health Ratings

These survey results revealed a notable trend that older participants are more aware of the air environment. When participants were asked if they “notice when air quality is poor”, 20 students responded “Yes”, 3 responded “I’m not sure”, and 3 responded “No”. All four students above the age of 18 indicated that they notice when air quality is poor. Of the next oldest age group: 15-17, 7 out of 8 participants responded that they notice when the air quality is poor. Every response recorded as “I’m not sure” or “No” came from students younger than 14. The majority of the older participants conveyed that they are aware of poor air quality, suggesting a correlation between age and air quality awareness. This emphasizes the necessity for younger individuals to learn about air quality and its effects on the environment and themselves. These findings underscore the importance of incorporating air quality education for younger age groups, ensuring that they develop awareness, to foster environmental consciousness.

Figure 4 illustrates that approximately 57.6% of participants indicated that air quality sometimes or often affects their mental health. Analysis of the responses revealed that 6 out of the 11 students who are “Never” affected by air quality were either under the age of 14. The only participant who reported being “Often” affected by air quality was in the 18-20 age range. It is possible to infer that younger participants, perhaps due to a lack of comprehensive understanding regarding air quality, demonstrate a lower reported impact on their mental health. It additionally suggests a potential correlation between age and perception of air quality’s impact on mental health.

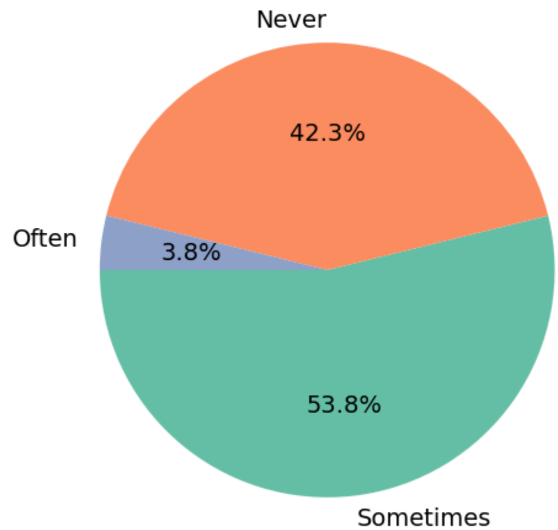

Figure 4: How much Air Quality affects Mental Health

Limitations

This scientific study, conducted on a small scale, encountered several notable limitations during project execution. One major limitation of this study was the minimal access to a diverse participant pool, which may have impacted the data results. About 50 percent of the participants were from California as opposed to different places in the United States. Upon reaching out to various schools, it became clear that most schools weren’t interested in participating in the questionnaire because of the perceived absence of tangible benefits for each educational institution.

Furthermore, the survey consisted of questions that required the participants to provide a deeper level of honest reflection. As the researcher, it was not possible to guarantee each participant's honesty, and variations based on each participant's perception of the survey's wording introduced a bias that may have influenced the study results. For the self-analysis questions in the survey, there were many uncontrollable variables in each participant's life, so air quality may not be a prominent factor. Factors such as mental health changes as a response to situations in one's personal life, and individual sensitivity to various environmental factors contributed to the complexity of drawing direct correlations with AQI.

To analyze the responses and put together the data with corresponding AQI values from PurpleAir, each participant provided their city and state location. The analysis revealed that due to multiple PM2.5 sensors in each city, the sensor used for data collection might not have been the closest to the participants' actual locations. This may alter the accuracy of the AQI data depending on the size of each city and the various number of sensors, as the accuracy of the collected data was compromised.

Another unknown variable is the time each participant spent outdoors, since the data incorporated outdoor air quality values, further complicating the interpretation of results. The lack of information regarding participants' outdoor activities introduced uncertainty since exposure to air pollutants outdoors differs widely for each individual. These limitations collectively underscore the need for a cautious interpretation of the study's findings and suggest avenues for improvement in future research endeavors.

Conclusions

This paper elucidates a survey of the potential effects that air quality has on students' productivity, motivation, and mental health. Using samples of data from the questionnaire, there is evidence that poor air quality correlates with a decrease in productivity, motivation levels, and mental health. Through the improvement of outdoor air quality, students may experience an increase in academic stimulation and success, allowing for further mental health improvements. The negative effects that air pollution has on students may have life-long impacts on their careers, which is why this issue needs to be actively addressed. The results therefore suggest that society's focus on the effects of air pollution should be extended beyond the immediate, acute health effects. Additional research in this field is necessary to investigate if there are broader implications regarding air quality and its connection to student academic performance and mental health. With more resources, it would be possible to expand the scope of the project to target a worldwide population to access data from different types of locations. Also, an additional study should extend the time-span for data collection, to include varying AQI values.

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