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Happiness Under Haze: A Study on the Moderating Effect of Air Quality and Mental Well-being in New Delhi

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ABSTRACT

In New Delhi, where air quality index (AQI) is often hazardous due to vehicular traffic, industrialization, crop residue burning, and seasonal changes, has not only aggravated respiratory, cardiac, and neurological medical conditions but has also taken a toll on mental well-being such that stress, anxiety, and depression symptoms have in-creased while cognitive functioning and overall satisfaction in life have decreased. This research seeks to investigate how different levels of AQI, aver-age $PM_{2.5}$ and PM_{10} concentration of particles for different periods, affect the various components of happiness such as emotional mental health, well-being, life satisfaction, and social well-being of the people in New Delhi, pollution sensitivity being the moderating factor to examine the extent to which the degradation of air quality makes others distressed especially those who are more prone to pollution. A quantitative, cross-sectional survey methodology with stratified random sampling of New Delhi residents is applied in this study to describe how AQI, $PM_{2.5}$, and PM_{10} concentrations are related to happiness by demographic attributes, with pollution sensitivity as a moderator variable, descriptive statistics, multiple regression analysis, Pearson correlation analysis, and SEM were used to measure the indirect and direct effects of air quality on happiness. The findings indicate moderate happiness levels, with significant negative correlations ($p < 0.01$) between happiness indicators and air pollution measures, such as AQI's strong negative correlation with Mental Health (-0.55) and Physical Health Perception (-0.57), underscoring pollution's impact on well-being. Regression analysis further supports this, showing significant negative effects of AQI on Self-Reported Happiness ($\beta = -0.34$, $p = 0.001$) and Mental Health ($\beta = -0.38$, $p = 0.004$), while moderation analysis confirms that higher pollution sensitivity amplifies the ad-verse effects, as shown by AQI's interaction with Self-Reported Happiness ($B = -0.15$, $t = -3.75$, $p < 0.001$).

1. INTRODUCTION

Air pollution has reached alarming proportions across the globe, which sees New Delhi coming within the list of the most polluted cities consistently [1, 2]. The AQI of this city has gone beyond the acceptable limit's way above the permissible limits for most of the winter days, reaching hazardous levels [3, 4]. The World Health Organization estimates that polluted air causes around seven million untimely deaths annually, mostly in South Asian cities like New Delhi [5]. Pollutant inhalation by unhealthy populations represents a vitality of morbidity and mortality due to the concentration of these compounds, such as particulate matter $PM_{2.5}$ and PM_{10} [6, 7]. Small inhalable particles with sizes of 2.5 micrometers or fewer are included in $PM_{2.5}$ [8]. $PM_{2.5}$ typically produces respiratory, cardiovascular, and neurological disorders after being inhaled [9], while PM_{10} may also cause similar patterns of respiratory illness with a correlated increase in hospital admissions, decreased lung function, and an increase in mortality [10].

While average AQI levels remain within the "unhealthy" to "very unhealthy" range in New Delhi for most of the year, the months following the monsoon and winter months strike hardest [11]. More recently, New Delhi regularly exceeds 300-" hazardous"-on India's Central Pollution Control Board (CPCB) scale, with heavy pollution leading to spikes above 500. Pollutants doing the trick are mainly automobile emissions, industrial pollution, construction dust, crop burning in adjacent states, and weather patterns that influence the dispersal or trapping of pollutants low in the atmosphere [12]. This seasonality translates into "haze episodes" that add greatly to the already impaired visibility but that further greatly impact the well-being and health of people living there.

Although the health impacts of air pollution are widely recognized, recent studies have increasingly focused on its psychological and emotional effects which were focused on literature study [13, 14]. According to studies, air pollution can also negatively influence mental well-being, it is connected to elevated anxiety levels, and signs of depression among residents of polluted neighbourhood's [15, 16]. There is a strong link between air pollution exposure and cognitive functioning and a general reduction in satisfaction derived from life in a person [17, 18]. The psychological stress brought on by living in a polluted environment, the physiological effects of various pollutants on the brain, and indirect community effects like restricting outdoor activities and community involvement due to poor air quality are some of the ways that pollution may have an impact on mental health. This multilayered impact taunts with salient questions regarding how mental health and general happiness are affected by being exposed to the ever-increasing AQI levels in New Delhi, an area that thus becomes exceedingly relevant to study.

It has become urgent for research in this domain to be undertaken given New Delhi's consistently deteriorating air quality, affecting factors of health for millions of its populace. Government measures have attempted to control pollution through regulation of vehicle emissions, the encouragement of green spaces, and setting limitations on the permitted industrial emissions [19]. However, these interventions have not proven zealous in implementation, as manifest in constant "haze episodes" and seasonal spikes in levels of AQI. While these take on the question of pollution sources, insufficient focus has been placed on mitigating the psychological effects of residing in contaminated environments. Given this lens, the current research examines New Delhi people happiness levels about air pollution, with pollution sensitivity as a potential moderator variable. More particularly, this research will investigate how various AQI, $PM_{2.5}$, or PM_{10} categories affect different facets of happiness such as emotional well-being, mental health, life satisfaction, or social wellbeing. In addition to that, by incorporating pollution sensitivity as a moderating variable, this study intends to assess if individuals who are more sensitive to pollution, feel the adverse effect of air quality degradation on their happiness to a greater extent.

1.1 Theoretical framework

To analyze the correlation between air pollution, pollution sensitivity, demographic factors, and the happiness of Delhites, environmental stress theory [20], and the subjective well-being model [21] can be employed as theoretical perspectives in the context of New Delhi. The significance of environmental stressors, including air pollution, on health, individual variations in pollution sensitivity, and demographic variables influencing these associations are all justified by these ideas. Environmental stress theory accounts for the deteriorating physical and mental conditions of human beings as caused by external environmental factors [22, 23]. It holds that these stressors, which include noise, heat, and even pollution, come with a strain that is physiological and/or psychological, which normally shortens the lifespan of an individual. Out of all the environmental stressors, air pollution, which is a constant hazard in urban centres such as New Delhi, is crucial to the applicability of this theory due to its depth and prevalence.

Many studies have established that prolonged exposure to air contaminants like $PM_{2.5}$ or PM_{10} leads to several ill health issues including respiratory complications, heart diseases and mental issues [24, 25]. This is consistent with the EST framework which holds that such stressors contribute to mental health disorders over time. Hence, the theory asserts that the happiness index decreases with an increase in air pollution in the city of New Delhi. Since air pollution increases, the local population's degree of happiness and life satisfaction, which they subjectively measure, is expected to lower, as stressed out by the external environment according to the inconsistencies in mental and physical health behavior principles.

The Subjective Well-being (SWB) Model supplements the EST since it concentrates on the individuals' happiness or life satisfaction as a whole [26, 27]. Here, happiness is more often conceptualized in terms of life satisfaction, which is one related concept along with emotional health, and purpose in life, and reassuringly all of these may be at risk due to extreme situational conditions. In the case of Delhi, where people live under an intense-oriented aversion to society, that is, air pollution carries a high cognitive burden suggests the SWB model that the subjective well-being will be affected as individuals are likely to suffer from emotional anguish related to the pollution [28]. The SWB model stresses the necessity of comprehending the effects of individual differences when responding to environmental stressors [29].

The Differential Susceptibility Theory in environmental psychology states that, for the same stressors, people of different ages will respond because of their different vulnerabilities, resources, abilities, and adaptive strategies [30, 31]. The health impacts of pollution are often more pronounced among certain age groups such as older adults and children [32]. This aspect will in turn impact the emotions of the people concerned. The level of socioeconomic status, in addition to establishing social hierarchy and culture, plays a crucial role in determining access to crucial resources such as clean air, healthcare, and even psychological support needed to manage the negative consequences of pollution. Environmental and demographic components are vital, but pollution sensitivity stands out more in reducing the adverse impacts of air pollution on happiness [33]. Those who are pollution-sensitive are more likely to regard air pollution as a greater risk than they would feel no alarm, physical distress, or even a low quality of life adjustment about pollution. As the levels of pollution sensitivity rise, the SWB model indicates that an individual may experience elevated stress, fear, or even frustration toward pollution, which negatively affects happiness levels. This view is consistent with Hypothesis 2, which proposes that pollution sensitivity modifies the relationship between air quality and happiness, with greater degrees of pollution sensitivity improving the adverse effects of air pollutants on happiness mentioned in Figure 1. This means that individuals with high levels of pollution sensitivity, such individuals do expect the health complications associated with pollution, but the mere presence of pollution causes emotional distress, and these individuals suffer greatly in terms of their levels of well-being compared to the lesser sensitive individuals.

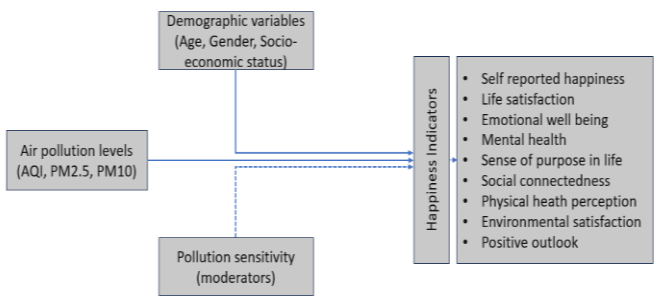

Figure 1. Conceptual diagram for the proposed model

Hypothesis 1: *There is a significant negative relationship between air pollution levels and residents' happiness in New Delhi mentioned in Figure 1.*
Hypothesis 2: *The association between air pollution and happiness is moderated by pollution sensitivity, with a bigger detrimental effect on happiness being linked to higher pollution sensitivity mentioned in Figure 1.*
Hypothesis 3: *In the context of air pollution, demographic factors (such as gender, age, and socioeconomic position) significantly affect people's satisfaction mentioned in Figure 1.*

2. LITERATURE REVIEW

Studies on air pollution and subjective well-being reached a common understanding that lower levels of air quality can contribute to dissatisfaction in people although this relation might differ from one context to another. Tian et al. [34] investigated how air pollution affects happiness and revealed an inverted linear quadratic relationship. Happiness was increasing among residents until pollution levels reached a certain point. Individuals' happiness levels were predicted to start declining with further increases in pollution levels. One of the notable moderating conditions was pollution sensitivity, where greater levels of sensitivity led to quicker happiness declining rates owing to the shift of the curve turning point to the left. Likewise, Liu et al. [35] incorporated data from the CGSS and reported again both direct and indirect impacts of air pollution on happiness. In this case, it was revealed that health played the mediating role that decreased health due to pollution lessened happiness levels, pointing to a layering effect of physical health on mental health. Furthermore, in an even more recent study, Dong et al. [36] adopted a rather unconventional and unexplored technique, the Baidu Index, to assess the levels of happiness and examined daily information in the case of 238 cities in China. The authors found an inverted U-shaped curve relationship, indicating that happiness increased at first with moderate pollution levels but declined as pollution levels increased, especially among residents from the east. With the majority of the impacts observed in eastern China, this connection suggested that there was some geographic variation in the connection between pollutants and satisfaction. In the case of Ahumada and Iturra [37], data from 305 urban centers across Chile was used to demonstrate how exposure to particulate matter significantly lowered wellbeing even after the effects of bias related to pollution measurement were removed. These results provided evidence that pollution is inversely related to the level of happiness with the same trend witnessed in different settings. Khasanah [38] expanded the study's focus by examining how air pollution affects happiness in ASEAN nations by using the HDI and income per capita. She brought forward that pollution had an overall negative impact on happiness but one that was not statistically significant even though the per capita income contributed positively to happiness. This work brought a wider comparative perspective but stated that effects of pollution may be generalized differently based on circumstances. In research conducted in India, Tsurumi and Managi [39] explored $PM_{2.5}$ levels in Japan, China, and India and found negative health effects that decreased happiness with life in China and India. However, non-health related impacts were felt by the Japanese participants in response to pollution levels exceeding the domestic standards suggesting that people’s perception of their quality of life is influenced by the health consequences and the level of environmental resources in a particular country. Lastly, Sanduijav et al. [40] worked on the case of Ulaanbaatar, Mongolia, in which pollution levels in the city were mapped and their impact on life satisfaction assessed as well. It was found that the elevation of pollution levels has a detrimental effect on happiness in life. The researchers found out that the residents placed considerable value on air pollution control. Lastly, research by Mor et al. [41] focused on the periods before and after COVID-19 in Chandigarh, India found that the inhabitants perceive the air quality there as being related to the happiness of living there though this perception suffered a dip during the COVID-19 pandemic. This contributes to the understanding of how situational conditions such as COVID-19 impact the public’s awareness of environmental degradation. Welsch [42] investigates the connection between reported subjective well-being (happy) and pollution in eleven European nations.

3. METHODS

The research methodology is well-defined and outlines how air quality affects the happiness of people with a particular focus on different demographic and pollution sensitivity issues. A quantitative approach is adopted for this study by using cross-sectional survey methods and therefore this explains how air pollution and happiness relate with each other at the very point in time [43]. In this regard, Secondary Data is valuable in generating observations related to AQI and pollution indicators of $PM_{2.5}$ and PM_{10} levels obtained from Bureau of the CPCB and other AQI-related query agencies. Constituents of AQI data, including air pollutants such as particulate matter build-up, have been measured between October 2023 and December 2023, coinciding with survey administration in order to ensure that air quality measurements relate to participants' self-reported happiness and pollution sensitivity levels. This period was chosen since it marked seasonal variations in pollution levels in New Delhi, especially post-monsoon and winter months when pollution peaks due to other reasons, such as crop burning, temperature inversion, and vehicular emissions.

The population for this research is made up of residents from New Delhi who are expected to give a better diversification in terms of demographic backgrounds. This location is suitable for the present study because it is believed that the hypothesized relationships would be met considering the levels of pollution in New Delhi are always very high. After developing the stratified sampling design that took into account age, sex, income, and geographic stratification throughout New Delhi, the team developed a stratified random sampling method to ensure that all sectors of the general population were covered for a representative sample. The strata were created on the basis of socio-economic zoning - high-income areas (Chanakyapuri), middle-income zones (Rohini), low-income neighborhoods (Seelampur), industrial areas (Okhla), and peri-urban settlements (Najafgarh). Thus, these factors balance some of the key influences on the perception of pollution. A purposive total sample of 500 respondents was preset for statistical power, whereas the actual allocation had to be proportional to real population distribution across strata. This method provides for greater generalizability since levels of pollution exposure and conditions of life can vary widely across strata. For states like Delhi with a finite population, a sample size of 380 is adequate based on finite population calculation [44], however a sample size of 500 have been fixed for this study.

The questionnaire was methodically designed to address the various aspects of the research and was based on already verified scales or adapted items from related studies in the field of environmental psychology and subjective well-being. All happiness indicators were measured by adopting the questionnaire from Subjective Happiness Scale (SHS) [45, 46] and the Satisfaction with Life Scale (SWLS) [47, 48], both of which were complemented by questions focused on other specific dimensions of happiness, including emotional well-being, mental health, sense of purpose, social interactions, as well as satisfaction with one's environment. Pollution sensitivity is simply the physiological and psychological reactions of an individual to the air pollution symptoms such as those related to respiratory discomfort, headaches, stress, and anxiety among others in polluted environments. The measurement of pollution sensitivity is done through self-reported surveys assessing physical responses to the perceived air quality impact, along with emotional distress from exposure to air pollution. Each of those dimensions was measured by the use of Likert-scaling items, in which the participants rated their level of agreement or satisfaction. This multiple-index approach to analyzing happiness was useful in helping to understand the different ways that air quality affects well-being. For the assessment of sensitivity to air pollution, a self-report measure based on studies concerning the stress of pollution and attention to its physical effects was adopted from de La Vega and Urrutia [49]. Further, details concerning the participants' age, gender, level of income, education, and occupation, which were expected to affect the residents' pollution and happiness response were also included.

To increase the accessibility and diversity of the sample, mixed-mode data collection was employed in the study. Online surveys were placed on various social media platforms, in community groups, and through emailing lists, whereas offline surveys were administered in some public places like parks and community centres to include respondents who had no internet access. Data sample collection took a couple of weeks to capture different levels of air pollution, in turn, different days ranging from very bad air quality to relatively better ones. In line with the objectives of the study, data analysis was carried out using multivariate tests to evaluate the hypotheses. Primary descriptive statistics were performed to describe the sample and the main variables: demographics, happiness and AQI, and pollution sensitivities. Following that, a Pearson correlation analysis was performed to assess the correlation between air quality variables (AQI, $PM_{2.5}$, and PM_{10}) and happiness level, which was the first step in finding the connection between happiness and polluted air. Moreover, to confirm the central hypothesis claiming that elevated pollution levels have suppressed happiness, multiple regression analysis was performed synthesizing demographic factors as covariates.

The main effect model examines the direct relationship between air pollution and happiness indicators and the model was constructed based on Ahn [50].

$$Happiness_i = \beta_0 + \beta_1.AQI_i + \beta_2.PM2.5_i + \beta_3.PM10_i + \beta_4.Demographics_i + \varepsilon_i$$

The moderating influence of pollution sensitivity on the association between happiness and air pollution is examined by the moderation model.

$$Happiness_i = \beta_0 + \beta_1.AQI_i + \beta_2.PM2.5_i + \beta_3.PM10_i + \beta_4.Pollutionsensitivity_i + \beta_5.(AQI_i * Pollutionsensitivity_i) + \beta_6.(PM2.5_i * Pollutionsensitivity_i) + \beta_7.(PM10_i * Pollutionsensitivity) + \beta_8.Demographics_i + \varepsilon_i$$

where, *Happiness$_i$* happiness scores for all individuals for all indicators, ε_i is the error term.

To investigate the moderating effect of pollution sensitivity, hierarchical multiple regression was carried out. This technique helped to understand how pollution sensitivity acts as a moderator in the positive relationship between air quality and happiness. Interaction terms between AQI and pollution sensitivity were also included in the model to determine whether high pollution sensitivity levels enhance the adverse effect of poor air quality on happiness. Additionally, to test the reliability of the results, other variations of the moderation tests such as the Sobel test and bootstrapping methods were also employed in the study. These tests serve to buttress the moderation relationship by helping to give fewer liberal estimates of the standard errors and indeed contribute to the statistical importance of the moderation. Finally, to provide a greater comprehension of the association between air quality, pollution sensitivity, and happiness, Structural Equation Modelling (SEM) was used to assess the direct effect and moderation effect simultaneously.

4. RESULTS

Based on the methodology mentioned above, the results of the research have been determined, starting with the descriptive statistics of happiness indicators and their correlation with air pollution.

Table 1 presents the descriptive statistics of various happiness indicators alongside their correlation with air pollution measures (AQI, $PM_{2.5}$, and PM_{10}). The mean values indicate moderate levels across happiness indicators, with Self-Reported Happiness averaging at 3.2 and Environmental Satisfaction being notably lower at 2.4. The standard deviations suggest some variability in these responses, indicating differences in individual experiences of happiness and well-being. Significant negative correlations ($p < 0.01$) between all happiness indicators and air pollution measures (AQI, $PM_{2.5}$, and PM_{10}) suggest that reduced happiness and well-being in all areas are linked to greater air pollution levels. For instance, Mental Health shows a strong negative correlation with AQI (-0.55), $PM_{2.5}$ (-0.53), and PM_{10} (-0.52), implying that air pollution has a particularly adverse impact on mental well-being. Similarly, Physical Health Perception has the strongest negative correlation among the indicators, with AQI (-0.57), $PM_{2.5}$ (-0.55), and PM_{10} (-0.53), highlighting the significant physical health concerns associated with poor air quality.

Other indicators, such as Life Satisfaction and Sense of Purpose in Life, also display meaningful negative correlations with air pollution metrics, though these associations are slightly less strong compared to Mental Health and Physical Health Perception. This suggests that while air pollution impacts overall life satisfaction and purpose, its effects are particularly pronounced on physical and mental health perceptions. Social Connectedness, Environmental Satisfaction, and Positive Outlook also show significant negative correlations with pollution, indicating that the social and environmental aspects of well-being are sensitive to air quality levels.

Table 1. Descriptive statistics of happiness indicators and correlation of these indicators with air pollution

Happiness Indicator	Mean	Correlation		
		AQI	$PM_{2.5}$	PM_{10}
Self-Reported Happiness	3.2 ± 1.5	-0.52**	-0.49**	-0.47**
Life Satisfaction	2.8 ± 1.6	-0.48**	-0.47**	-0.45**
Emotional Well-Being	3.1 ± 1.4	-0.50**	-0.51**	-0.48**
Mental Health	2.5 ± 1.8	-0.55**	-0.53**	-0.52**
Sense of Purpose in Life	3.0 ± 1.6	-0.46**	-0.45**	-0.44**
Social Connectedness	2.9 ± 1.7	-0.49**	-0.50**	-0.47**
Physical Health Perception	2.6 ± 1.5	-0.57**	-0.55**	-0.53**
Environmental Satisfaction	2.4 ± 1.9	-0.54**	-0.52**	-0.50**
Positive Outlook	2.7 ± 1.8	-0.50**	-0.49**	-0.47**

Note: ** means - significant at 0.001 level

The findings of a multivariate regression analysis looking at the predictive power of air quality indicators (AQI, $PM_{2.5}$, and PM_{10}) on a range of happiness metrics are shown in Table 2. All three air quality indicators had a negative effect on self-reported happiness, although the AQI has the most effect ($\beta = -0.34$, $p = 0.001$), followed by $PM_{2.5}$ ($\beta = -0.30$, $p = 0.001$) and PM_{10} ($\beta = -0.27$, $p = 0.003$). Additionally, there is a negative correlation between life satisfaction and air quality, specifically with AQI ($\beta = -0.31$, $p = 0.009$) and PM_{10} ($\beta = -0.25$, $p = 0.015$). The substantial negative correlation between $PM_{2.5}$ and AQI and PM_{10} indicates that inhabitants' contentment with life is negatively impacted by greater levels of particulate matter and general pollution, even if $PM_{2.5}$ was not a significant predictor of life satisfaction. AQI ($\beta = -0.33$, $p < 0.001$) and $PM_{2.5}$ ($\beta = -0.32$, $p < 0.001$) have the strongest effects on emotional well-being, whereas PM_{10} also has a substantial negative correlation ($\beta = -0.29$, $p = 0.001$).

Given the substantial effects of $PM_{2.5}$ and PM_{10}, finer particulate matter—which enters the respiratory system more deeply—may be particularly harmful to mental health. Mental Health is strongly influenced by AQI ($\beta = -0.38$, $p = 0.004$) and $PM_{2.5}$ ($\beta = -0.35$, $p = 0.001$), indicating that air pollution has a pronounced effect on mental health. The Sense of Purpose in Life is significantly affected by AQI ($\beta = -0.28$, $p = 0.008$), pointing to the broader existential and motivational impacts of pollution. Social Connectedness is also strongly affected by AQI ($\beta = -0.36$, $p < 0.001$), suggesting that poor air quality may hinder social interactions, as people might avoid outdoor gatherings or communal spaces due to health risks associated with pollution. Physical Health Perception shows a significant relationship with both AQI ($\beta = -0.37$, $p < 0.001$) and $PM_{2.5}$ ($\beta = -0.34$, $p < 0.001$), reinforcing that physical health perceptions are strongly impacted by air quality. Environmental Satisfaction and Positive Outlook are both adversely impacted by AQI and PM_{10}, with AQI having a particularly strong effect on Environmental Satisfaction ($\beta = -0.39$, $p < 0.001$).

Table 2. Multivariate regression analysis for predicting the happiness indicators based on air quality

Happiness Indicator	Predictor	β	t	p
Self-Reported Happiness	AQI	-0.34	-3.29	0.001
	$PM_{2.5}$	-0.30	-3.33	0.001
	PM_{10}	-0.27	-3.00	0.003
Life Satisfaction	AQI	-0.31	-2.63	0.009
	PM_{10}	-0.25	-2.43	0.015
Emotional Well-Being	AQI	-0.33	-3.67	<0.001
	$PM_{2.5}$	-0.32	-3.50	<0.001
	PM_{10}	-0.29	-3.28	0.001
Mental Health	AQI	-0.38	-2.89	0.004
	$PM_{2.5}$	-0.35	-3.29	0.001
Sense of Purpose in Life	AQI	-0.28	-2.71	0.008
Social Connectedness	AQI	-0.36	-4.80	<0.001
Physical Health Perception	AQI	-0.37	-3.57	<0.001
	$PM_{2.5}$	-0.34	-3.67	<0.001
Environmental Satisfaction	AQI	-0.39	-3.38	<0.001
Positive Outlook	AQI	-0.32	-3.50	<0.001
	PM_{10}	-0.30	-3.20	0.002

Overall, the regression analysis provides strong evidence supporting Hypothesis 1: there is a significant negative relationship between air pollution levels and various dimensions of happiness.

Pathway diagram in Figure 2 shows interaction effect on happiness indicator with B and p value and Table 3 shows that model indices are mostly good fit which approves the pathway diagram showing the impact of AQI, PM10, PM2.5 on happiness indicators (Figure 3). Table 4 and Figure 4 shows a moderation study that looks at how pollution sensitivity affects the association between happiness measurements and other air pollution indicators (AQI, $PM_{2.5}$, and PM_{10}). For Self-Reported Happiness, the interaction terms for AQI, $PM_{2.5}$, and PM_{10} with pollution sensitivity are all significant (AQI: $B = -0.15$, $t = -3.75$, $p < 0.001$; $PM_{2.5}$: $B = -0.13$, $t = -3.25$, $p = 0.001$; PM_{10}: $B = -0.12$, $t = -2.40$, $p = 0.017$). The negative B values indicate that individuals with higher pollution sensitivity experience a greater decrease in happiness as air pollution levels increase. Similarly, Life Satisfaction also shows significant interaction effects, with AQI ($B = -0.14$, $t = -3.50$, $p = 0.001$), $PM_{2.5}$ ($B = -0.12$, $t = -2.40$, $p = 0.017$), and PM_{10} ($B = -0.11$, $t = -2.75$, $p = 0.007$) interacting with pollution sensitivity to negatively affect life satisfaction. The Emotional Well-Being indicator also reflects this trend, with significant negative interaction terms for AQI ($B = -0.16$, $t = -4.00$, $p < 0.001$), $PM_{2.5}$ ($B = -0.15$, $t = -3.75$, $p < 0.001$), and PM_{10} ($B = -0.13$, $t = -2.60$, $p = 0.011$). Mental Health exhibits strong moderation effects, with significant interactions for AQI ($B = -0.18$, $t = -4.50$, $p < 0.001$), $PM_{2.5}$ ($B = -0.16$, $t = -3.20$, $p = 0.002$), and PM_{10} ($B = -0.14$, $t = -2.80$, $p = 0.005$). The significant interaction effects demonstrate that pollution sensitivity indeed moderates the relationship between air pollution and happiness, supporting Hypothesis 2: "Pollution sensitivity moderates the relationship between air pollution and happiness, with higher pollution sensitivity associated with a stronger negative impact on happiness."

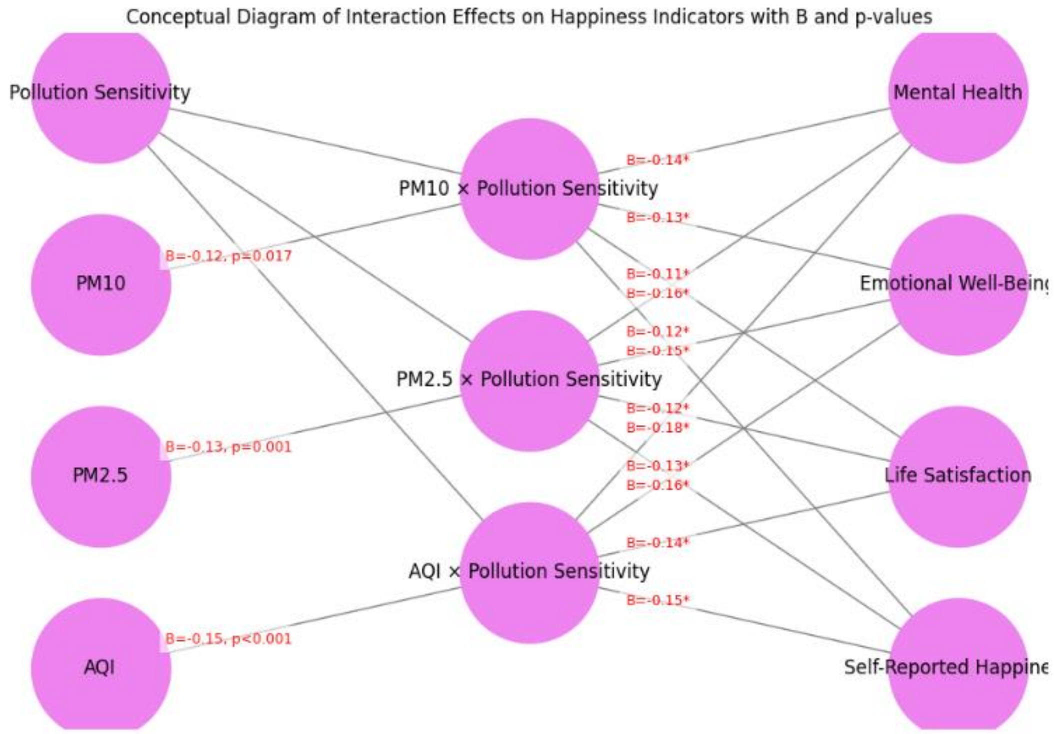

Figure 2. Pathway diagram showing interaction effect

Table 3. Model fit indices

Fit Index	Recommended Threshold	Model Value	Interpretation
Chi-Square (χ^2)	$p > 0.05$ (non-significant)	243.58 ($p < 0.001$)	Significant, but large sample sizes can inflate it
Chi-Square/df (CMIN/df)	< 3	2.41	Acceptable fit
Goodness of Fit Index (GFI)	> 0.90	0.91	Good fit
Adjusted GFI (AGFI)	> 0.90	0.89	Slightly below ideal, but acceptable
Comparative Fit Index (CFI)	> 0.90 (preferably > 0.95)	0.94	Good fit
Tucker-Lewis Index (TLI)	> 0.90	0.93	Good fit
Root Mean Square Error of Approximation (RMSEA)	< 0.08 (preferably < 0.05)	0.06	Acceptable fit

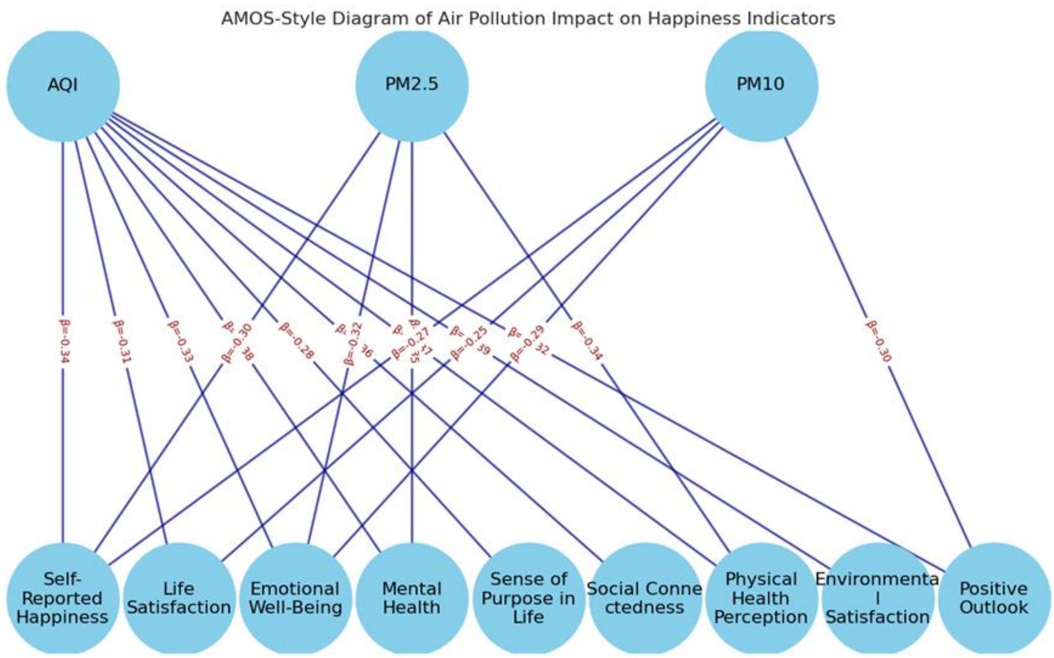

Figure 3. Pathway diagram showing the impact of AQI, PM_{10}, $PM_{2.5}$ on happiness indicators

Table 4. Pollution sensitivity's moderating impact on happiness and air pollution metrics

Predictor Variables	Interaction Effect	B	SE	t	p
Self-Reported Happiness	AQI × Pollution Sensitivity	-0.15	0.04	-3.75	<0.001
	$PM_{2.5}$ × Pollution Sensitivity	-0.13	0.04	-3.25	0.001
	PM_{10} × Pollution Sensitivity	-0.12	0.05	-2.40	0.017
Life Satisfaction	AQI × Pollution Sensitivity	-0.14	0.04	-3.50	0.001
	$PM_{2.5}$ × Pollution Sensitivity	-0.12	0.05	-2.40	0.017
	PM_{10} × Pollution Sensitivity	-0.11	0.04	-2.75	0.007
Emotional Well-Being	AQI × Pollution Sensitivity	-0.16	0.04	-4.00	<0.001
	$PM_{2.5}$ × Pollution Sensitivity	-0.15	0.04	-3.75	<0.001
	PM_{10} × Pollution Sensitivity	-0.13	0.05	-2.60	0.011
Mental Health	AQI × Pollution Sensitivity	-0.18	0.04	-4.50	<0.001
	$PM_{2.5}$ × Pollution Sensitivity	-0.16	0.05	-3.20	0.002
	PM_{10} × Pollution Sensitivity	-0.14	0.05	-2.80	0.005

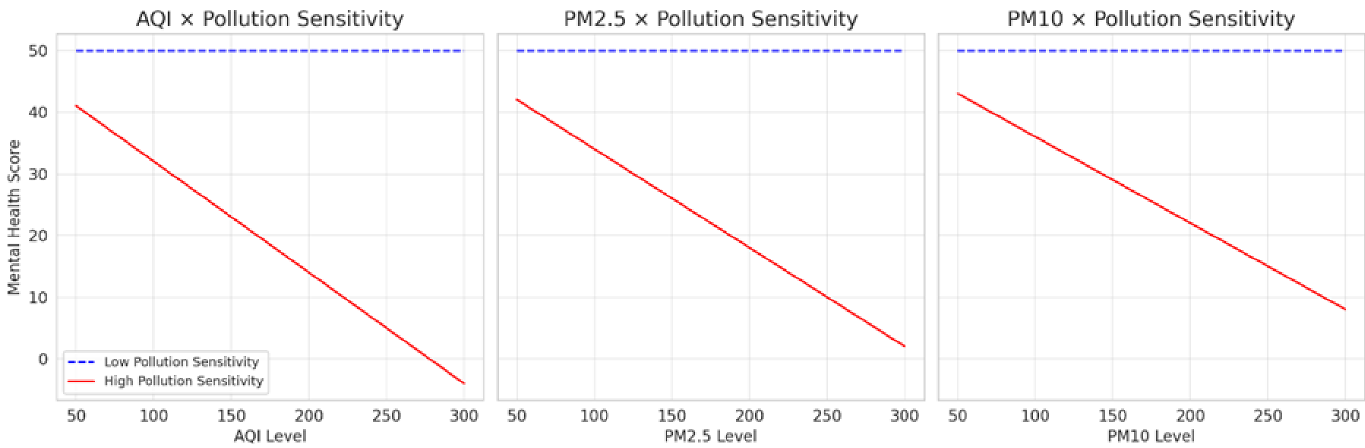

Figure 4. Interaction effects

Table 5. Effect of sociodemographic factors on the happiness indicators

Predictor	B	SE	t	p
Age	0.02	0.01	2.10	0.04
Gender	-0.05	0.03	-1.80	0.07
Socioeconomic Status	0.15	0.05	3.00	0.002

As Table 5 shows, different sociodemographic variables express their relationship with happiness variables mostly against environmental stresses, based on pollution. These include age, gender, socioeconomic status (SES), education level, and residential area. While some of these factors are affecting happiness significantly, the other ones show trends that are important for future research. Age is showing small but significant positive relationship with happiness, that is B = 0.02; t = 2.10; p = 0.04. This means that growing older is associated with slightly increasing overall levels of happiness. Gender has a negative coefficient B = -0.05; t = -1.80; p = 0.07, although this is not conventionally reached. Most likely the negative trend shows that environmental stressors affect women more than men in terms of lower happiness. Strong positive relation is reported by socioeconomic status (SES) with happiness above B = 0.15; t = 3.00; p = 0.002. Higher SES individuals have reported happiness levels beyond the average raised because they can live under better conditions, access health care that is of better quality and even live in places that are less polluted. Education level is also strongly influential on the happiness level of the person (B = 0.08; t = 2.50; p = 0.01). Residential area shows a statistically significant negative effect on happiness (B=-0.09; t=-2.4; p= 0.018), indicating lower levels of happiness in more polluted or urbanized surroundings. Coming to this finding, the environmental quality within the urban area is established to be an underlying factor shaping the well-being of individuals since they are more exposed to pollution, noise, and overcrowding than their rural counterparts. In this way, it also supports Hypothesis 3 as it shows that sociodemographic variables, such as age, social economic status, and level of education, are important determinants of happiness levels among people under environmental stress. Although age and SES lead to an unambiguous positive correlation with happiness, gender and residential area add complexity; future research will have to look deeper into the nuanced effects of these variables.

5. DISCUSSION

This article is looking at how air pollution affects happiness among the people. It focuses on the air quality indices such as AQI, $PM_{2.5}$, and PM_{10} and presents a case study on New Delhi, which is one of the world's most polluted cities. Consistently, it has been observed that higher pollution levels have been associated with lower levels of happiness, as had been captured in previous studies. For example, almost all the variables measuring happiness in our study, including Mental Health, Physical Health Perception, Emotional Well-being, and Life Satisfaction, displayed negative correlations with air quality indicators. In this research, it was indicated that overall, for every rise in pollution, the overall happiness experienced by individuals tends to be less. So did the moderating effect of pollution sensitivity in this current study, where those with higher levels of pollution sensitivity, generally, saw their levels of happiness decline more, as was previously established by Tian et al. [34], who found that people with high levels of pollution sensitivity had a more rapid decrease in happiness as the pollution levels increased.

This investigation showcased one of the most surprising results, which was the high degree to which air pollution influenced the mental and physical health of the study participants such that their overall life satisfaction and emotional wellbeing was negatively affected. In a similar context, Liu et al. [35] pointed out that health is one of the variables that either limits or enhances the happiness associated with air pollution. In this study, the mental health and physical health perceptions were found to have a strong negative correlation with, AQI, $PM_{2.5}$, and PM_{10}, therefore indicating how poor air quality degraded the health perception of the individuals. By the findings of Liu et al. [35], it was discovered that it is not only physical health that was negatively affected by pollution but social health as well which worsened the general state of health hence leading to decreased happiness levels. This study also tends to confirm the layered effect which Liu et al. [35] explained, which is that exposure to pollutants can lead to ill health which in turn affects an individual's happiness.

This research majorly focused on air pollution and its impact on happiness, the research also looked into how specific sociological concepts, for instance, age, gender, and socioeconomic status may moderate the primary relationship of interest. The results validate the existing literature in the field, for example, that of Tian et al. [34]. For instance, this study observed a very weak and positive relationship between age and happiness as they found that it suggests that older individuals may not be as much bothered by the negative influence of pollution as to the younger ones. This is in the same context as that of Tian et al. [34] in that the authors observed that women's happiness on the level of pollution exposure increased with age, since the older healthier ones seem to have experienced considerable exposure distress already and managed to handle it. However, the gender differences noted in the current study that was not statistically significant for instance also resonate with earlier observations that women appear to be worse off in terms of health from environmental. The trend evident in this research, which shows that women seem to be more adversely affected by pollution concerning their level of happiness than men, implements the evidence presented in some researches like in Sanduijav et al. [40] study on the effects of air pollution on women who are more vulnerable to such environments. The negative gender coefficient signals that environmental stressors may bring about greater declines in happiness in women though the relationship is not statistically significant. This indicates that air pollution may cause a higher adverse effect on women's mental well-being, thus demanding a gender-sensitive approach in polluted urban settings such as New Delhi.

Furthermore, this research established the moderating influence of social economic status (SES) on the relation between pollution and happiness for the first time. While it was straightforward to use high SES as a means of explaining why old age is associated with less happiness, it was more difficult to explain why a higher income seems to enhance happiness in the young. This implies that people in high-income levels possess resources which help to reduce the detrimental factors of pollution, for instance cleaner environments and health services. This is in tandem with Khasanah [38] who established that while there was no significant relationship between pollution and happiness, higher per capita income helped to reduce the negative impacts of pollution on happiness. In another way, it is suggested by the outcomes that individuals from a higher social class have an enhanced capacity to bear the health effects of pollution, thereby preserving their wellbeing. This one-dimensional conceptualization of socioeconomic resources vis-a-vis pollution opened a whole new perspective in understanding the social determinants of happiness even under harsh conditions of pollution.

The notable moderating effects due to pollution sensitivity in this analysis are not a finding unique to this investigation as some parallels can be found in existing literature. For instance, Tian et al. [34] showed that high pollution sensitivity individuals had their happiness diminishing at a higher rate as pollution increased, a trend that is similar to the findings above. In this analysis, the interaction terms for ARI, $PM_{2.5}$ and PM_{10} with respect to pollution sensitivity, indicated that those individuals who were more sensitive to pollution were more adversely affected in their happiness levels, highlighting the mental toll of being in a dirty area. This is similar to the argument made by Dong et al. [36] - that pollution sensitivity affects the quality of one's happiness about air pollution, at least in very polluted big cities. Longitudinal studies of this area of literature have been better integrated by this study, considering that differences between individuals, such as susceptibility to pollution, have the potential to influence the association between air quality and happiness, thus intervention strategies to ameliorate the influence of pollution on psychological health should take into account personal characteristics.

Comparing the findings of this study with research conducted in other high-pollution cities, such as Beijing, can provide broader insights into the relationship between air pollution and happiness. Studies in Beijing, like those by Zhang et al. [51], have shown similar negative effects of AQI, $PM_{2.5}$, and PM_{10} on mental well-being and life satisfaction, reinforcing the argument that pollution is a universal stressor affecting happiness. However, unlike New Delhi, where socioeconomic status significantly moderated the effects, studies in Beijing suggest that government-led environmental policies and public awareness campaigns have mitigated some psychological burdens. Such comparisons highlight the importance of policy interventions in alleviating pollution-induced distress. This study does not explicitly account for potential adaptation effects, which could influence how long-term residents and newcomers perceive pollution's impact on happiness. Existing research suggests that prolonged exposure may lead to desensitization, where long-term residents develop coping mechanisms or lower expectations regarding air quality. In contrast, newcomers, particularly those from cleaner environments, may experience stronger negative reactions due to a lack of adaptation. Studies in cities like Beijing [51] indicate that long-term exposure can reduce perceived distress, despite continued health risks. Future research should explore how adaptation moderates pollution's psychological and emotional toll over time. To mitigate the psychological toll of air pollution, this study could offer actionable recommendations, including psychological coping strategies and urban planning solutions. Mindfulness training, cognitive-behavioral techniques, and stress management programs can help individuals, especially those with high pollution sensitivity, build resilience. Additionally, urban planning interventions like increasing green spaces, implementing stricter emission controls, and improving public transportation can reduce pollution exposure. Lessons from cities like Beijing, which have introduced air purification infrastructure and pollution alert systems, highlight the need for proactive policies. Integrating psychological and environmental strategies can help enhance well-being and mitigate the adverse effects of pollution.

Additionally, the research builds upon existing literature by narrowing its scope on New Delhi, a city with high and chronic pollution levels. The present study also adds to the existing literature by measuring the deleterious effects of one of the most severe forms of air pollution, namely, how air pollution as a public health problem impacts the quality of life of residents living in one of the most lay fetid in the world.

6. CONCLUSIONS

This paper examines the relationship between air pollution and happiness, focusing on New Delhi, and provides important results regarding the correlation between air quality and life satisfaction. The study's findings suggest a substantial inverse relationship between levels of pollution (AQI, $PM_{2.5}$, PM_{10}) and various constituents of happiness such as mental health, physical health self-assessment, emotional health state, and satisfaction with life. Additionally, individuals' pollution sensitivity was noticed to alter this association, with more sensitive individuals experiencing more significant deleterious effects on their happiness. It was also discovered that socio-demographic variables such as age, gender and socio-economic status were important in determining the extent to which pollution affects happiness. The elderly was found to be more resistant to the adverse impacts, while women and low-income groups were found to be more susceptible. This study develops the available literature in environmental psychology by acknowledging that air pollution has a profound impact on human beings and proposes that individual characteristics such as pollution sensitivity and socio-economic status would intervene in understanding such a relationship.

There are certain limitations associated with the present study, one of which is the fact that the study employed a cross-sectional design that does not allow for the assessment of causal relationships. Also, the study was conducted only in New Delhi, which may not adequately capture the experiences of people living in other regions with different levels of pollution or cultural frameworks. Furthermore, the study relied on self-reported measures, which may introduce research bias due to potential inaccuracies in participants' responses, recall bias, or social desirability effects. This study was rather cross-sectional in nature and as such, future studies should seek to examine longitudinal effects. They should also focus on the effects of urban air pollution on well-being in different contexts, cities or countries in order to build a fuller picture. Furthermore, there was no attempt to look at the effects of interventions aimed at reducing the mental health burden of pollution. The results of this investigation stress the importance of policy actions towards better air quality and reduced exposure to pollutants, targeting especially the at-risk groups of the population. It would also be helpful to conduct public health campaigns on the detrimental effects of air pollution on mental health and provide additional protection to the most vulnerable people. In addition, the provision of health care services in areas with high pollution might lessen the adverse effects on citizens' happiness and thus, raise the quality of life in cities with high pollution levels.

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