The Effect of Air Pollution on Suicidal Ideation: The Mediating Role of Basic Social Emotions on Microblogging Platforms

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Date: 2025-01-10T00:00:00+00:00

Abstract

Air pollution is intimately connected with human existence, exerting profound influences on physical and mental health as well as behavioral patterns. This study leverages big data analytics to investigate the relationship between air pollution and suicide ideation in China from 2010 to 2020, and to examine the mediating role of fundamental social emotions expressed on microblogging platforms. The findings reveal: (1) Only three negative emotions—anger, disgust, and sadness—function as complete mediators between CO_2/SO_2 emissions and suicide ideation. Specifically, CO_2 emissions demonstrate a significant negative effect on suicide ideation through these three emotions, whereas SO_2 emissions exhibit a significant positive effect. (2) Both per capita healthcare resources and per capita disposable income of residents affect suicide ideation via the emotions of happiness, anger, disgust, and sadness, thereby illuminating the role of macro-level factors in suicide risk. (3) The two-way fixed effects model indicates that after controlling for province and year fixed effects and incorporating emotional mediating variables, the direct effects of CO_2 and SO_2 emissions on suicide ideation are relatively limited; furthermore, with the exception of disgust, all other emotions display significant positive influences on suicide ideation. These findings furnish scientific evidence for comprehending the long-term impacts of air pollution on suicide ideation and for developing intervention strategies, with the ultimate objective of reducing suicide rates and promoting public health.

Full Text

Preamble

The Impact of Air Pollution on Suicidal Ideation: The Mediating Role of Basic Social Emotions in Microblogs

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Abstract

Air pollution is intimately connected to human existence, affecting our physical and mental health as well as behavior. Using big data analytics, this study investigates the relationship between air pollution and suicidal ideation in China from 2010 to 2020, examining the mediating role of basic social emotions expressed on microblogs. The findings reveal: (1) Only three negative emotions —anger, disgust, and sadness—fully mediate the relationship between CO_2/SO_2 emissions and suicidal ideation. Specifically, CO_2 emissions exert a significant negative influence on suicidal ideation through these three emotions, whereas SO_2 emissions produce a significant positive effect. (2) Both per capita healthcare resources and per capita disposable income affect suicidal ideation through emotions such as happiness, anger, disgust, and sadness, demonstrating the role of macro-level factors in suicide risk. (3) The two-way fixed effects model shows that after controlling for province and year effects and including emotional mediators, the direct effects of CO_2 and SO_2 emissions on suicidal ideation are relatively limited, and except for disgust, all other emotions demonstrate significant positive effects on suicidal ideation. These results provide a scientific basis for understanding the long-term impact of air pollution on suicidal ideation and for developing intervention strategies aimed at reducing suicide and improving public health.

Keywords: air pollution; suicidal ideation; mediating effect; structural equation model; microblog

Rapid industrialization and urbanization have made air pollution a global environmental issue with profound impacts on human health and social well-being. Since the 18th National Congress of the Communist Party of China, the Chinese government has prioritized air pollution control, implementing the "Air Pollution Prevention and Control Action Plan" and the "Three-Year Action Plan to Win the Battle for Blue Skies" to ensure air quality improvement. In 2017, the Ministry of Environmental Protection launched a year-long intensive inspection campaign to verify the effectiveness of previous air pollution control efforts. These initiatives have driven significant improvements in air quality, with substantial reductions in PM2.5 concentrations and heavy pollution days, making the battle for blue skies a cornerstone of the broader pollution prevention campaign.

Suicide encompasses any implicit or explicit intention, thought, or action to end one's own life. Research on suicide involves multiple constructs including suicide ideation, suicide intent, suicide plan, suicide attempt (or failed suicide attempt), and suicidal behavior (Chehil & Kutcher, 2012, p. 23). Suicidal ideation refers to having clear thoughts of suicide and preparing for a fatal, self-directed harmful

act, but without a specific plan. Scholars have begun exploring the reasons behind gender ratios in suicide rates among Chinese populations, proposing the Strain Theory of Suicide (Zhang, 2019). Suicidal ideation can be triggered by life events that generate conflict, frustration, psychological distress, hopelessness, or even despair—these can be termed psychological stressors. This model posits that when individuals experience psychological stress they cannot resolve, they suffer psychological torment and anger. The external release of anger manifests as violence toward others, while internal release of stress may lead to depression, anxiety, self-harm, or suicidal thoughts (Wang & Wang, 2023).

The health impacts of air pollution are multifaceted, encompassing not only respiratory and cardiovascular diseases (Beelen et al., 2014) but also potential effects on mental health that may influence suicide risk. Furthermore, particulate matter can alter brain chemistry within 24 hours, modifying aggression and emotional control (Calderón-Garcidueñas et al., 2003). The physiological and psychological hazards of air pollution to respiratory, cardiovascular, or nervous system functions affect individual health (Xiang et al., 2017). The environmental stress model suggests that the stressful or pathogenic effects of air pollution are complex and indirect, emphasizing that adverse effects of air pollution are moderated by individual cognitive processes, which in turn influence behavioral and health responses to air pollution in complex and subtle ways (Xiang et al., 2017). However, the impact of air pollution on suicide risk and the role of emotions in this relationship remain unclear.

Levinson (2012) investigated air quality effects by daily surveying respondents' subjective well-being, while Power et al. (2015) analyzed the relationship between fine particulate pollution and generalized anxiety based on respondents' scores on anxiety disorder scales. These studies are limited by sample size and the subjectivity of self-report surveys, making it difficult to comprehensively and authentically reflect emotional changes in large populations (Yang et al., 2020; Zhang & Wang, 2019). Lim et al. (2012) conducted a three-year follow-up study of elderly individuals at a community center in Korea, finding that depressive symptoms intensified as air pollution concentrations increased. Basic social emotions play an important role in the relationship between air pollution and suicidal ideation. For instance, disgust is a primary emotional factor leading to suicide, as individuals may commit suicide due to self-disgust. Many psychological problems stem from disgust toward surrounding people or things, and individuals with suicidal behavior exhibit extreme self-disgust, indicating dysfunction in their disgust response (Xiao et al., 2023). Previous research has rarely combined time-series data with social media sentiment analysis, limiting deeper understanding of the dynamic relationships among air pollution, emotions, and suicide risk. Among the potential adverse effects of air pollution, emotional responses may be the most sensitive, yet in real-world contexts, sensitive emotional reactions may originate from various external stimuli. Therefore, based on existing research, a definitive causal relationship between air pollution and negative emotions cannot be established (Xiang et al., 2017).

Therefore, this study selects the period from 2010 to 2020 to investigate the relationship between air pollution and suicide risk in China, examining the mediating role of basic social emotions on microblogs. Reviewing data from this period in 2024 holds significant importance. First, this timeframe covers a critical stage of China' s air pollution governance, providing a valuable opportunity to assess policy effectiveness and understand how changes in air pollution affect public health. Second, with the rise of social media, platforms like Weibo have become important channels for reflecting public sentiment, offering new perspectives for studying emotional changes. Additionally, advances in big data and natural language processing technologies now enable more accurate analysis and quantification of Weibo emotions, providing new tools and methods for research. Finally, this study helps us better understand the mechanisms through which air pollution affects mental health, providing a scientific basis for developing effective interventions to reduce suicide incidents and improve public health.

2 Methods

This study aims to explore the relationship between air pollution and suicidal ideation, and to deeply analyze the mediating role of basic social emotions expressed on microblogs in this relationship.

2.1 Data Collection

This study selected carbon dioxide (CO_2) and sulfur dioxide (SO_2) as representative indicators of air pollution to construct an air pollution index as the independent variable. Specifically, we collected annual emission data for CO_2 and SO_2 across 31 provinces, municipalities, and autonomous regions in China from 2010 to 2020, using air pollutant emission data and carbon emission statistics.

To obtain microblog text data, we employed web scraping programs to collect publicly available Weibo posts geolocated within China' s 31 provinces, municipalities, and autonomous regions from 2010 to 2020. To ensure data representativeness and processing efficiency, we used a random sampling strategy, selecting one-thousandth of the sample to construct our specialized Weibo text dataset for this study. Based on this dataset, we utilized the Lincui Analysis System to extract variables related to suicidal ideation and basic social emotions on microblogs.

This study uses suicidal ideation as the dependent variable, constructing a suicide risk index. This variable was derived from specific "suicidal ideation" word categories in the Chinese suicide dictionary carefully constructed by Lv et al. (2015). Using the Lincui Analysis System, we performed word segmentation and meticulous classification, identification, and filtering of the content in our specialized Weibo text dataset, counting the frequency of "suicidal ideation" word categories for each province and year as a quantitative indicator of suicide risk levels.

In this study, basic social emotions on microblogs serve as mediating variables, specifically including happiness as a positive emotion, and sadness, anger, fear, and disgust within the negative emotion category. To systematically extract and quantify these emotional variables, we adopted the microblog basic emotion lexicon carefully constructed by Dong et al. (2015) as our core tool. This lexicon comprehensively covers vocabulary related to the five basic social emotions—happiness, sadness, anger, fear, and disgust—providing a solid foundation for sentiment analysis. Based on this lexicon, we conducted in-depth sentiment analysis of our specialized Weibo text dataset, precisely identifying and extracting word frequencies corresponding to these five basic social emotions. These word frequency data were aggregated by year and province as mediating variables measuring basic social emotions on microblogs, constructing a mental health index.

To ensure research rigor and reliability of results, this study selected two variables—per capita disposable income of all residents and per capita healthcare resources—as control variables based on macroeconomic indicator panel data for China' s 31 provinces, municipalities, and autonomous regions from 2010 to 2020.

2.2 Data Processing and Analytical Methods

During data processing, we first standardized the raw data by converting all variable values into Z-scores, eliminating dimensional differences between variables and achieving dimensionless data to ensure comparability in subsequent analyses. In terms of analytical methods, we employed multiple statistical techniques to deeply explore relationships among variables. First, we conducted descriptive statistical analysis to report overall distribution characteristics of the data, summarizing central tendency and dispersion. Next, we used Pearson correlation analysis to preliminarily reveal associations and their strength among variables. Based on this, to guard against potential multicollinearity issues that could interfere with results, we further performed collinearity diagnostics to ensure independence of model variables. Additionally, we conducted Hausman tests to compare the goodness-of-fit of fixed effects models, random effects models, and ordinary least squares regression models, selecting the most appropriate model for subsequent analysis.

To control for potential confounding variables, we introduced a two-way fixed effects model. This model simultaneously considers province fixed effects and time fixed effects during estimation, controlling for time-invariant provincial characteristics and time-specific factors that could affect model results, thereby more accurately revealing the true relationship between air pollution and suicidal ideation.

To deeply investigate the complex relationships among air pollution, mental health, and suicidal ideation, we constructed a structural equation model (SEM). In the SEM model, we simultaneously estimated direct and indirect effects to

explore both the direct impact of air pollution on suicidal ideation and the mediating role of basic emotions on microblogs as mental health variables, revealing how emotional states serve as psychological mechanisms mediating the relationship between air pollution and suicidal ideation.

3 Results

3.1 Descriptive Statistics and Correlation Analysis

Descriptive statistical analysis was conducted on air pollution indicators (CO_2 and SO_2), five basic social emotions on microblogs, suicidal ideation, per capita disposable income, and per capita healthcare levels, with results shown in Table 1 .

Table 1 Descriptive Statistics of Variables

[Table content would appear here]

Data were standardized to enable comparison and relationship exploration across different variables. To examine basic relationships among variables, we first conducted Pearson correlation analysis, with results shown in Table 2 .

Table 2 Correlation Analysis Results

[Table content would appear here]

Note: N = 341; ** indicates $p < 0.001$, ** indicates $p < 0.01$, * indicates $p < 0.05$; two-tailed tests; same below.*

Correlation analysis reveals that CO_2 emissions show a significant negative correlation with suicidal ideation, whereas SO_2 emissions show a significant positive correlation with suicidal ideation. Additionally, happiness demonstrates a significant negative correlation with suicidal ideation, meaning higher levels of happiness correspond to lower suicidal ideation. Anger, sadness, and disgust show significant positive correlations with suicidal ideation, indicating that higher levels of these negative emotions correspond to higher suicidal ideation. Further analysis shows that both per capita healthcare resources and per capita disposable income exhibit significant negative correlations with suicidal ideation, suggesting that better medical resources and economic conditions are associated with lower suicidal ideation.

3.2 Collinearity Diagnostics

To ensure independence among independent variables in the regression model and avoid multicollinearity effects on estimation results, this study conducted collinearity diagnostics. According to the diagnostic results (see Table 3), all VIF values are less than 10, indicating no serious multicollinearity issues and meeting model estimation assumptions.

Table 3 Multicollinearity Test Results

[Table content would appear here]

3.3 Model Selection

Using Stata software for model selection tests, results show: (1) Comparing fixed effects model with OLS regression, $p < 0.001$, indicating significant fixed effects and that the fixed effects model is significantly superior to OLS regression; (2) Comparing random effects model with OLS regression, $p < 0.001$, indicating significant random effects and that the random effects model is superior to OLS regression; (3) Hausman test comparing fixed effects and random effects models, $p < 0.001$, indicating significant differences between them, with the fixed effects model being more appropriate.

Table 4 Model Comparison Test Results

[Table content would appear here]

Comprehensive results indicate that the fixed effects model performs best, explaining 61.9% of variance in the dependent variable ($R^2 = 0.627$; adjusted $R^2 = 0.619$, accounting for model degrees of freedom).

3.4 Mediation Effect Analysis

Further investigation of how CO_2 and SO_2 emissions affect suicidal ideation through happiness revealed that happiness does not mediate the relationship between CO_2/SO_2 emissions and suicidal ideation. When happiness was included in the regression equation, direct effects remained significant, indicating that happiness failed to function as a mediator. However, socioeconomic factors (per capita healthcare resources and per capita disposable income) demonstrated significant partial mediation in their effects on suicidal ideation.

Table 5 Mediation Effect Analysis for Happiness

[Table content would appear here]

Controlling for per capita healthcare resources and per capita disposable income, per capita healthcare resources showed a significant positive indirect effect on suicidal ideation through happiness, $\beta = 0.042$, Boot SE = 0.015, 95% CI [0.013, 0.071], with the mediation effect accounting for 15.32% of the total effect. Per capita disposable income showed a significant negative indirect effect on suicidal ideation through happiness, $\beta = -0.034$, Boot SE = 0.013, 95% CI [-0.060, -0.008], with the mediation effect accounting for 6.87% of the total effect. These results suggest that economic conditions may indirectly influence suicidal ideation by enhancing subjective well-being (happiness).

Investigating how CO_2 and SO_2 emissions affect suicidal ideation through anger revealed that CO_2 has a significant negative indirect effect on suicidal ideation through anger, with the mediation effect accounting for 69.62% of the total effect. SO_2 emissions have a significant positive indirect effect on suicidal ideation through anger, with the mediation effect accounting for 67.49% of the total

effect. These results indicate that anger plays an important mediating role between CO_2/SO_2 emissions and suicidal ideation, with the direction of effects depending on pollutant type.

Table 6 Mediation Effect Analysis for Anger

[Table content would appear here]

Controlling for per capita healthcare resources and per capita disposable income, anger partially mediates the relationship between per capita disposable income and suicidal ideation, while fully mediating the relationships between CO_2 or SO_2 emissions and suicidal ideation, as well as between per capita healthcare resources and suicidal ideation. Both CO_2 emissions and per capita healthcare resources have significant negative indirect effects on suicidal ideation through anger, while SO_2 emissions and per capita disposable income have significant positive indirect effects. These findings suggest that CO_2 emissions may reduce suicidal ideation through anger, possibly reflecting a protective psychological regulation function of anger, whereas SO_2 emissions may increase suicidal ideation through anger, indicating that pollutants may increase psychological risk through emotional intensification mechanisms.

Investigating how CO_2 and SO_2 emissions affect suicidal ideation through disgust revealed that CO_2 emissions have a significant negative indirect effect on suicidal ideation through disgust, with disgust fully mediating the relationship between CO_2 emissions and suicidal ideation. The mediation effect accounts for 101.34% of the total effect, indicating a suppression effect. SO_2 emissions have a significant positive indirect effect on suicidal ideation through disgust, with disgust partially mediating this relationship, accounting for 81.19% of the total effect. The suppression effect of disgust (particularly in the context of CO_2) suggests that the potential protective effect of CO_2 emissions may be masked inversely by disgust, while SO_2 emissions may exacerbate psychological discomfort and increase suicidal ideation by triggering disgust.

Table 7 Mediation Effect Analysis for Disgust

[Table content would appear here]

Controlling for per capita healthcare resources and per capita disposable income, disgust partially mediates the relationship between per capita disposable income and suicidal ideation, while fully mediating the relationships between CO_2 or SO_2 emissions and suicidal ideation, as well as between per capita healthcare resources and suicidal ideation. Both CO_2 emissions and per capita healthcare resources have significant negative indirect effects on suicidal ideation through disgust, while SO_2 emissions and per capita disposable income have significant positive indirect effects.

Investigating how CO_2 and SO_2 emissions affect suicidal ideation through sadness revealed that CO_2 emissions have a significant negative indirect effect on suicidal ideation through sadness, with sadness fully mediating the relationship between CO_2 and suicidal ideation, accounting for 90.59% of the total effect.

SO_2 emissions have a significant positive indirect effect on suicidal ideation through sadness, with sadness partially mediating this relationship, accounting for 81.35% of the total effect. The mechanism of sadness is similar to that of disgust: CO_2 emissions may provide psychological protection by alleviating sadness, while SO_2 emissions may deteriorate mental health by intensifying sadness.

Table 8 Mediation Effect Analysis for Sadness

[Table content would appear here]

Controlling for per capita healthcare resources and per capita disposable income, sadness partially mediates the relationship between per capita disposable income and suicidal ideation, while fully mediating the relationships between CO_2 or SO_2 emissions and suicidal ideation, as well as between per capita healthcare resources and suicidal ideation. CO_2 emissions, per capita healthcare resources, and per capita disposable income all have significant negative indirect effects on suicidal ideation through sadness, while SO_2 emissions have a significant positive indirect effect.

Investigating how CO_2 and SO_2 emissions affect suicidal ideation through fear revealed that when fear was included in the regression equation, direct effects remained significant while indirect effects were not significant. Fear does not mediate the relationship between CO_2 emissions and suicidal ideation, nor does it mediate the relationship between SO_2 emissions and suicidal ideation. This suggests that fear may lack significant influence in the context of CO_2 and SO_2 emissions, indicating a weaker role in the psychological mechanisms of suicidal ideation.

Table 9 Mediation Effect Analysis for Fear

[Table content would appear here]

Controlling for per capita healthcare resources and per capita disposable income, when fear was included in the regression equation, only the direct effect of per capita disposable income was significant, with no significant indirect effects. Fear does not mediate relationships between any independent variables and suicidal ideation, though it suggests CO_2 emissions may have a negative indirect effect on suicidal ideation through fear.

Further analysis using the two-way fixed effects model showed that after controlling for province and year effects, the relationships between CO_2 ($p > 0.05$) and SO_2 emissions ($p > 0.05$) and suicidal ideation were not significant, indicating that these two environmental variables may have weak direct effects on suicidal ideation.

The effects of CO_2 and SO_2 emissions on suicidal ideation may not be direct but rather manifested through other mediating variables (such as mental health, social environmental stress) or specific contexts (such as extreme pollution events).

Therefore, this study further considered emotional mediators to re-examine the relationship between the air pollution index and suicidal ideation.

After controlling for province and year effects and including emotional mediators, the relationships between CO_2 and SO_2 emissions and suicidal ideation remained non-significant ($p > 0.05$), indicating weak direct effects of these environmental variables on suicidal ideation. However, except for disgust (Model 5), all other emotions showed significant positive effects on suicidal ideation.

3.5 Cross-Lagged Analysis

We employed Mplus for random-intercept cross-lagged panel analysis, constructing models using data from 31 Chinese regions for the early (2013), middle (2017), and late (2020) stages of air pollution control, with happiness as the mediating variable, temporarily excluding covariates "per capita disposable income" and "per capita healthcare resources." The model failed to produce standardized results, preventing causal inference due to non-convergence.

Possible reasons include: (1) Insufficient sample size: recommendations suggest at least 5 times the number of parameters, but this study only had 31 cases (31 provinces, autonomous regions, and municipalities); (2) Overly complex model: too many paths or factor loadings were specified as free parameters. Attempts to simplify the model by fixing some parameters or removing unnecessary paths, or including only two time points (2013, 2020) with just the independent variable (CO_2) and dependent variable (suicidal ideation), still resulted in non-convergence.

4 Discussion and Conclusion

This study integrated mediation analysis, two-way fixed effects models, and cross-lagged analysis to explore the relationship between air pollution and suicidal ideation in China from 2010 to 2020, examining the mediating role of basic social emotions on microblogs. Through big data analysis, we found that different air pollutant types produce distinct mechanisms affecting suicidal ideation. CO_2 primarily reduces suicidal ideation through negative indirect effects (via anger, disgust, and sadness), possibly reflecting certain psychological protective mechanisms that may be related to the non-direct threats posed by higher CO_2 levels to health and psychology. In contrast, SO_2 primarily increases suicidal ideation through positive indirect effects (via anger, disgust, and sadness), demonstrating the negative psychological effects of pollutants, possibly related to acute health threats or stress induced by pollution exposure.

Moreover, the role of macro-level factors cannot be ignored. Both per capita healthcare resources and per capita disposable income affect suicidal ideation through emotions (happiness, anger, disgust, sadness). The negative indirect effect of per capita healthcare resources suggests that adequate public health resources may reduce psychological burden. The positive indirect effect of per

capita disposable income may be related to economic pressure or social inequality.

Although the direct effects of CO_2 and SO_2 on suicidal ideation are not significant, indirect effects emerge through certain emotional variables (particularly disgust, anger, and sadness). The effects of emotions also differ between pollutants. The full mediation and suppression effects of disgust and sadness indicate non-linear roles of emotions between pollutants and suicidal ideation. Anger appears as the primary pathway for the psychological effects of pollutants, with effect direction depending on pollutant type.

This study provides deep insights into the central role of emotional mechanisms in the association between air pollution and suicidal ideation, which not only advances understanding of air pollution' s impact on mental health but also offers new perspectives for policy development. Based on these findings, we recommend that governments addressing air pollution should not only focus on reducing pollutant emissions, especially SO_2, but also increase investment in mental health, particularly in heavily polluted areas and high-risk populations. First, governments can implement stricter environmental regulations to promote emission control in industrial and transportation sectors, reducing the release of harmful substances like SO_2 to mitigate health hazards from the source. Second, for populations significantly affected by air pollution, governments should strengthen mental health support systems, including mental health education, counseling services, and intervention measures, particularly in heavily polluted cities and regions, providing regular mental health screenings and coping strategies.

Additionally, at the societal level, enhancing public emotion regulation capabilities and psychological resilience can reduce the negative impact of emotional problems on suicidal ideation. Through public education and awareness campaigns, improving residents' understanding of the relationship between air pollution and mental health can promote individual emotion management and mental health enhancement, thereby reducing the potential negative effects of environmental pollution on suicidal ideation.

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Note: Figure translations are in progress. See original paper for figures.