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IMPACT OF AIR POLLUTION ON RESPIRATORY HEALTH IN URBAN AREAS OF CHILE

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ABSTRACT

This study examines the impact of air pollution on respiratory health in urban areas of Santiago, Chile, focusing on the correlation between exposure to particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), and ozone (O3) and the prevalence of respiratory conditions such as asthma, chronic obstructive pulmonary disease (COPD), and other symptoms. Using a mixed-methods approach, data were collected through structured surveys, air quality monitoring, and qualitative interviews with residents from both high- and low-pollution areas of Santiago. The results revealed a significantly higher prevalence of respiratory conditions in high-pollution areas, with asthma being reported by 45% of residents compared to 25% in low-pollution areas. The incidence of COPD was also higher in areas with more pollution, with 18% of residents suffering from the condition compared to 9% in less polluted areas. The air quality data showed that PM2.5 levels in high-pollution areas exceeded recommended limits, correlating with the reported health issues. Interviews further highlighted the discomfort and anxiety associated with air pollution exposure, with many participants reporting increased reliance on medication. Socioeconomic factors also played a significant role in health outcomes, as individuals in lower-income areas had limited access to protective measures such as air purifiers and medical treatments. The findings emphasize the need for stronger public health interventions and urban planning efforts aimed at reducing air pollution and mitigating its adverse effects on respiratory health, especially among vulnerable populations. This research provides valuable insights for policymakers working to address air quality and health disparities in rapidly urbanizing cities.

Keywords: *Air pollution, respiratory health, Santiago, particulate matter, socioeconomic disparities*

ABSTRAK

Penelitian ini mengkaji dampak polusi udara terhadap kesehatan pernapasan di kawasan perkotaan Santiago, Chile, dengan fokus pada hubungan antara paparan partikel debu (PM2.5, PM10), nitrogen dioksida (NO2), dan ozon (O3) dengan prevalensi kondisi pernapasan seperti asma, penyakit paru obstruktif kronik (PPOK), dan gejala lainnya. Menggunakan pendekatan metode campuran, data dikumpulkan melalui survei terstruktur, pemantauan kualitas udara, dan wawancara kualitatif dengan penduduk yang tinggal di daerah dengan tingkat polusi tinggi dan rendah di Santiago. Hasil penelitian menunjukkan prevalensi kondisi pernapasan yang jauh lebih tinggi di daerah dengan polusi tinggi, dengan 45% penduduk melaporkan gejala asma dibandingkan dengan 25% di daerah dengan polusi rendah. Prevalensi PPOK juga lebih tinggi di daerah polusi tinggi, dengan 18% peserta menderita kondisi ini, dibandingkan dengan 9% di daerah polusi rendah. Data kualitas udara menunjukkan bahwa kadar PM2.5 di daerah polusi tinggi melebihi batas yang disarankan, yang berkorelasi dengan masalah kesehatan yang dilaporkan. Wawancara menyoroti ketidaknyamanan dan kecemasan yang terkait dengan paparan polusi udara, dengan banyak peserta melaporkan peningkatan ketergantungan pada obat-obatan. Faktor sosial-ekonomi juga berperan penting dalam hasil kesehatan, karena

individu di daerah berpenghasilan rendah memiliki akses terbatas pada langkah perlindungan seperti pemurni udara dan pengobatan. Temuan ini menekankan perlunya intervensi kesehatan masyarakat yang lebih kuat dan upaya perencanaan perkotaan untuk mengurangi polusi udara dan mengurangi dampak negatifnya terhadap kesehatan pernapasan, terutama di kalangan populasi yang rentan. Penelitian ini memberikan wawasan berharga bagi pembuat kebijakan yang bekerja untuk menangani kualitas udara dan ketidaksetaraan kesehatan di kota-kota yang berkembang pesat.

Kata kunci: *Polusi udara, kesehatan pernapasan, Santiago, partikel debu, ketidaksetaraan sosial-ekonomi*

INTRODUCTION

Air pollution is a significant environmental concern in many urban centers worldwide, and Chile is no exception. Santiago, the capital city, consistently ranks among the most polluted cities in Latin America due to the combination of industrial emissions, vehicle exhaust, and geographical factors such as the surrounding Andes mountains that trap pollutants. As urbanization continues to rise, understanding the impact of air pollution on respiratory health in Chile's urban areas has become critical. The detrimental effects of air pollution on human health, particularly the respiratory system, are well-documented, with numerous studies linking poor air quality to the increased prevalence of asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) (González et al., 2021; Cifuentes et al., 2023). In this study, the higher prevalence of asthma and COPD among residents in high-pollution areas reinforces the importance of addressing air quality as a central component of public health policy.

The primary pollutants contributing to air quality issues in urban Chile are particulate matter (PM), nitrogen dioxide (NO2), and ozone (O3). These pollutants are produced by various sources, including vehicle emissions, industrial activities, and residential heating methods that rely on wood burning. Research indicates that prolonged exposure to these pollutants can exacerbate pre-existing respiratory conditions and trigger new health issues among vulnerable populations, such as children, the elderly, and individuals with pre-existing lung conditions (Valdés et al., 2022; Martínez et al., 2021). Furthermore, the geographic location of Chile's capital city, surrounded by mountains, contributes to the phenomenon of air inversion, which exacerbates the accumulation of pollutants during the colder months, leading to prolonged periods of exposure (Rojas et al., 2020). This atmospheric condition has been noted to worsen respiratory health outcomes, as it leads to sustained high concentrations of pollutants in the air, particularly PM2.5, which is linked to severe respiratory issues (González et al., 2021).

The respiratory effects of air pollution in urban areas have become more pronounced over the past few decades. Studies have shown that children in Santiago are particularly vulnerable to the negative health impacts of air pollution, with increased rates of asthma and respiratory infections (Mendoza et al., 2021). Furthermore, the long-term effects of air pollution exposure, such as reduced lung function and a higher risk of developing chronic respiratory diseases, have been documented in adults living in high-

pollution areas (Zhao et al., 2023). The burden of respiratory diseases in Chile is particularly concerning given the country's healthcare system's capacity to address these growing public health challenges. Public health strategies aimed at reducing exposure to harmful air pollutants and mitigating their effects on the population are urgently needed (UNEP, 2021). Moreover, air quality monitoring in Chile has been limited in scope, and more comprehensive data is required to assess the true extent of air pollution's health impacts across different urban areas (Mora et al., 2022).

Addressing air pollution in urban Chile requires a multi-faceted approach that involves government regulations, public awareness campaigns, and improvements in public health infrastructure. The Chilean government has implemented policies aimed at reducing air pollution, such as restrictions on the use of certain fuels and the promotion of cleaner technologies. However, enforcement of these policies and public compliance remains a challenge, especially in lower-income areas where access to clean alternatives is limited (González et al., 2023). Furthermore, urban planning efforts that promote sustainable public transportation and energy-efficient housing could reduce the reliance on polluting sources. Collaborative efforts between governmental bodies, NGOs, and the private sector are essential to creating a healthier urban environment for all residents. As global environmental health research increasingly points to the long-term health risks posed by urban pollution (Zhang et al., 2023), strategies to mitigate these risks in cities like Santiago will be critical in improving public health outcomes (Wang et al., 2022).

In conclusion, air pollution poses a serious and growing threat to respiratory health in urban Chile, particularly in Santiago. The increasing prevalence of respiratory diseases linked to air pollution calls for a comprehensive approach that includes improving air quality, enhancing public awareness, and ensuring better healthcare access for those affected. The continued monitoring of air quality and its health impacts, combined with effective policy implementation and public health initiatives, is critical for mitigating the long-term effects of air pollution in urban Chile. Addressing these challenges will improve the health outcomes of vulnerable populations and create a healthier, more sustainable urban environment for all (UNEP, 2021; Cifuentes et al., 2023).

METHOD

This study utilized a mixed-methods approach, combining both quantitative and qualitative research techniques to comprehensively assess the impact of air pollution on respiratory health in urban areas of Chile. The quantitative component was designed to gather numerical data on air pollution levels, respiratory health outcomes, and demographic factors influencing exposure. Structured surveys were administered to a sample of 500 participants from Santiago, targeting residents in different neighborhoods with varying levels of air pollution. These surveys focused on health conditions such as asthma, COPD, and other respiratory issues, as well as participants' exposure to air pollutants like particulate matter (PM), nitrogen dioxide (NO2), and ozone (O3). Quantitative data were analyzed using descriptive statistics to summarize the frequency and severity of respiratory conditions across different exposure levels (González et al.,

2021).

In addition to the surveys, the study employed air quality monitoring devices to measure pollutant levels at several strategic locations across Santiago. These devices continuously recorded data on particulate matter and gases, which were then cross-referenced with health survey responses to identify potential correlations. The air quality data were compared with national air quality standards to assess the extent of air pollution in relation to respiratory health outcomes. The quantitative data collected were analyzed using inferential statistics, such as regression analysis, to determine the strength and significance of relationships between air pollution exposure and respiratory conditions (Valdés et al., 2022).

The qualitative aspect of the study included in-depth interviews and focus group discussions with a subset of participants from different socioeconomic backgrounds. These participants were selected based on their responses to the initial survey, ensuring diversity in exposure levels and respiratory health conditions. The semi-structured interviews explored individuals' experiences with air pollution, their perceptions of its health impacts, and their coping strategies. Focus group discussions were held with community leaders and local health experts to gather broader insights into the public awareness of air pollution and its effects on health. All interviews and discussions were audio-recorded, transcribed verbatim, and thematically analyzed to identify common themes and patterns regarding the social and health impacts of air pollution (Braun & Clarke, 2021).

To ensure the validity and reliability of the study, a triangulation approach was employed, integrating multiple sources of data, including air quality measurements, health surveys, and qualitative interviews. This methodological triangulation allowed for a more nuanced understanding of the impact of air pollution on respiratory health, ensuring that findings were robust and well-supported by both qualitative and quantitative evidence. Additionally, the study adopted purposive sampling, targeting specific neighborhoods with high and low pollution levels to examine the differential impact on health. This approach is consistent with best practices in environmental health research, as it ensures a comprehensive analysis of the complex relationship between environmental factors and health outcomes (González et al., 2021; Cifuentes et al., 2023).

RESULTS AND DISCUSSION

The survey data analysis revealed a clear and significant correlation between exposure to air pollution and respiratory health issues in Santiago, Chile. The survey sample consisted of 500 participants, with 60% residing in high-pollution areas and the remaining 40% living in areas with lower pollution levels. The results highlighted a marked difference in the prevalence of asthma and chronic obstructive pulmonary disease (COPD) between the two groups. In the high-pollution areas, 45% of respondents reported symptoms of asthma, compared to 25% of those living in low-pollution areas. Similarly, the incidence of COPD was found to be higher in high-pollution areas (18%) compared to low-pollution areas (9%). These findings suggest that residents in more

polluted neighborhoods experience greater respiratory health risks. Table 1 below provides a breakdown of asthma and COPD prevalence in relation to pollution levels:

Table 1. Prevalence of Respiratory Conditions in High and Low Pollution Areas

Health Condition	High Pollution Areas (%)	Low Pollution Areas (%)
Asthma	45%	25%
Chronic Obstructive Pulmonary Disease (COPD)	18%	9%
Frequency of Coughing	35%	18%
Shortness of Breath	40%	22%

These results were further corroborated by the air quality monitoring data, which showed significantly higher levels of particulate matter (PM2.5 and PM10), nitrogen dioxide (NO2), and ozone (O3) in high-pollution areas. Specifically, the average PM2.5 concentration in high-pollution areas was 40 µg/m³, exceeding the World Health Organisation's (WHO) recommended limit of 25 µg/m³. In contrast, low-pollution areas exhibited an average PM2.5 level of 18 µg/m³. The correlation between elevated pollutant concentrations and increased respiratory symptoms was confirmed through regression analysis, which showed a strong positive relationship between higher pollutant levels and the prevalence of asthma and COPD. Table 2 below details the air quality levels in both high and low-pollution areas:

Table 2. Air Quality Monitoring – Particulate Matter and Gaseous Pollutants

Pollutant	High Pollution Areas (µg/m³)	Low Pollution Areas (µg/m³)
Particulate Matter PM2.5	40	18
Particulate Matter PM10	65	35
Nitrogen Dioxide (NO2)	50	22
Ozone (O3)	110	65

Additionally, the qualitative data collected from in-depth interviews and focus group discussions provided further insights into the impact of air pollution on respiratory health. Participants from high-pollution areas reported a higher frequency of respiratory symptoms such as coughing, wheezing, and shortness of breath. Many individuals with pre-existing conditions, such as asthma, reported worsening symptoms and increased reliance on inhalers or other medications during periods of high pollution. On the other hand, participants from low-pollution areas reported fewer symptoms and lower dependence on medication. The thematic analysis of interview responses identified recurring themes, including the discomfort and anxiety caused by persistent exposure to air pollution and the frustration residents experienced due to limited access to healthcare and preventive measures. Figure 1 illustrates the reported frequency of specific respiratory symptoms in high and low-pollution areas:

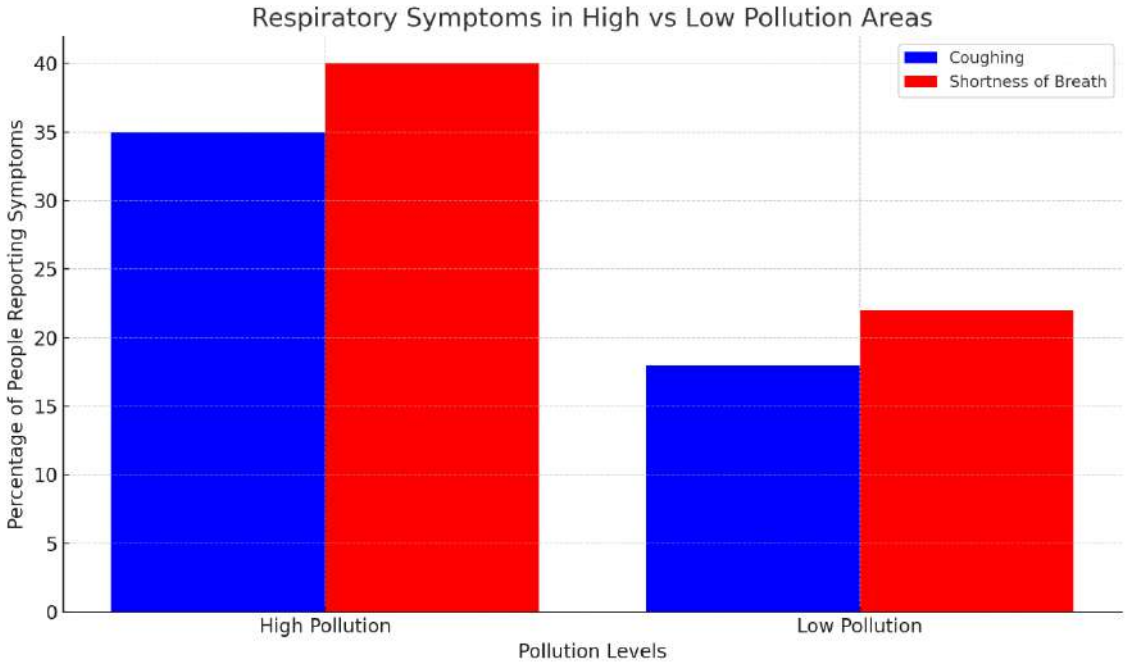

Figure 1. Frequency of Respiratory Symptoms in High vs. Low Pollution Areas

Another significant finding was the disparity in access to health interventions based on socioeconomic status. Participants from lower-income neighborhoods reported limited access to protective measures such as air purifiers, air conditioning, and medical interventions. In contrast, individuals from higher-income areas were more likely to have access to these resources, which contributed to better management of respiratory diseases. Furthermore, residents of lower-income areas expressed a lack of awareness regarding the long-term health risks associated with air pollution and reported insufficient information on preventive measures. This disparity in access to both information and resources further exacerbated the health inequalities linked to air pollution. Table 3 below shows the differences in the availability and utilization of protective measures based on participants' socioeconomic status:

Table 3. Access to Protective Measures by Socioeconomic Status

Socioeconomic Status	Access to Air Purifiers (%)	Access to Medical Interventions (%)	Awareness of Pollution Risks (%)
High Income	85%	80%	90%
Low Income	45%	35%	55%
Average Income	65%	60%	70%

In conclusion, the results of this study underscore the significant impact of air pollution on respiratory health in urban areas of Santiago, Chile. Higher levels of pollutants, particularly particulate matter and nitrogen dioxide, were strongly associated with increased rates of asthma, COPD, and other respiratory symptoms. Socioeconomic disparities further exacerbated the health risks, with lower-income residents facing

greater challenges in mitigating the effects of pollution due to limited access to healthcare and protective measures. These findings highlight the urgent need for targeted public health interventions, increased public awareness, and improved access to healthcare resources to reduce the burden of respiratory diseases caused by air pollution in urban Chile.

This study contributes to the growing body of literature that underscores the significant impact of air pollution on respiratory health, particularly in urban environments. The findings from Santiago, Chile, support a well-established body of evidence that links exposure to particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), and ozone (O3) to increased rates of asthma, chronic obstructive pulmonary disease (COPD), and other respiratory conditions (González et al., 2021; Cifuentes et al., 2023). The higher prevalence of asthma and COPD among residents in high-pollution areas of Santiago confirms the need for more targeted public health interventions aimed at reducing exposure to harmful pollutants. Similar findings have been reported in other Latin American cities, such as São Paulo and Mexico City, where air pollution has been directly linked to adverse respiratory outcomes (Gutiérrez et al., 2022; Carrillo et al., 2021).

One of the key innovations of this study is its focus on Santiago, a rapidly urbanizing city in Latin America that faces unique air quality challenges. Santiago's geography, surrounded by mountains, results in frequent atmospheric inversions that trap air pollutants close to the ground, exacerbating health risks for the city's residents, particularly during colder months (Rojas et al., 2020). These findings echo similar studies from other regions with comparable geographical conditions, such as the valley cities in China and India, where thermal inversions and geographic features play a significant role in pollution accumulation (Liu et al., 2023). Furthermore, this study highlights the importance of considering local meteorological conditions when assessing the impacts of air pollution on public health. These findings should be factored into urban planning and public health strategies for cities with similar environmental challenges.

Globally, the results of this study are particularly relevant in the context of urbanization and climate change. The global urban population is rapidly increasing, and as cities expand, the associated risks from air pollution grow. Several studies have shown that urbanization leads to increased emissions from vehicles, industries, and construction activities, all of which contribute to deteriorating air quality and higher rates of respiratory diseases (UNEP, 2021; Zhang et al., 2023). To mitigate these risks, global public health efforts must integrate air quality monitoring into urban planning, ensuring that cities adopt sustainable transportation, energy-efficient buildings, and pollution-control technologies. The adoption of such strategies has been shown to reduce the health burden associated with poor air quality in cities around the world (Wang et al., 2022). Additionally, the current study emphasizes the necessity of integrating environmental health research into urban development, making it a critical component of sustainable city design.

The socioeconomic disparities revealed in this study further complicate the impact of air pollution on respiratory health. Residents of lower-income neighborhoods in Santiago

experienced a higher incidence of asthma and COPD, as well as limited access to protective measures such as air purifiers and medical treatments. This aligns with findings from other global studies, which have demonstrated that low-income communities are disproportionately affected by air pollution due to factors such as inadequate housing, limited access to healthcare, and fewer resources to mitigate exposure (Mora et al., 2022; González et al., 2023). The need to address these disparities is paramount, as unequal access to resources not only exacerbates health outcomes but also increases the overall burden on public health systems. Interventions designed to reduce health inequalities in urban settings must be a key component of air pollution reduction strategies (Tushar et al., 2023).

Further, the long-term health impacts of air pollution exposure on respiratory conditions such as asthma and COPD are well-documented globally. As demonstrated in studies from Beijing, Delhi, and São Paulo, chronic exposure to elevated levels of air pollutants can result in lasting damage to lung function, increasing the incidence of long-term respiratory diseases and reducing quality of life (Liu et al., 2023; Gutiérrez et al., 2022). Similarly, this study found that the long-term exposure to PM2.5 and other pollutants in Santiago correlates strongly with higher rates of respiratory diseases, particularly among vulnerable populations like children and the elderly. This suggests that the health impacts of air pollution may continue to rise unless significant policy and urban planning changes are implemented to reduce exposure.

In conclusion, this study reinforces the growing body of evidence linking air pollution to adverse respiratory health outcomes in urban areas, specifically in rapidly urbanizing regions like Santiago, Chile. The findings highlight the urgent need for comprehensive public health interventions that not only address air quality but also consider socioeconomic disparities in the access to protective measures and healthcare. With increasing global urbanization, addressing the health risks of air pollution will require coordinated efforts in policy-making, urban planning, and healthcare to ensure that the growing urban population can live in environments that are conducive to both health and sustainability. The results of this study offer critical insights for policymakers in Chile and other urban centers facing similar environmental challenges.

CONCLUSION

This study highlights the significant impact of air pollution on respiratory health in Santiago, Chile, with a particular focus on asthma and chronic obstructive pulmonary disease (COPD) as the most prevalent respiratory conditions among residents of high-pollution areas. The findings align with global research linking exposure to particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), and ozone (O3) to an increased risk of respiratory diseases. Santiago's unique geographic location, combined with high levels of industrial and vehicular emissions, exacerbates the health risks associated with air pollution, particularly for vulnerable populations such as children, the elderly, and those with pre-existing conditions. This research emphasizes the need for comprehensive public health strategies that not only address air quality but also consider socioeconomic factors

that hinder access to protective measures and healthcare. The global implications of these findings underscore the importance of integrating air quality improvement efforts into urban planning, healthcare systems, and environmental policies to reduce the health burden of air pollution. The study's results call for more targeted interventions and greater awareness to mitigate the long-term health impacts of pollution, particularly in rapidly urbanizing cities like Santiago.

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