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Investigation of the Relationship between Air Pollution and Respiratory Health Outcomes in Pakistan

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ABSTRACT

In developing countries such as Pakistan, the problem of air pollution is growing as industrialization, urbanization and limited environment regulations make its way to deteriorating air quality. The relationship between air pollution and respiratory health outcomes in Pakistan is investigated using epidemiological data, air quality indices and hospital admissions for respiratory diseases. Air pollution has become a major public health problem in Pakistan — due to urbanization, industrial expansion and population growth — the findings show, calling for targeted interventions and policy to mitigate the negative impact of air pollution on public health. This study explores spatial interconnections between air pollution and respiratory health outcomes across variable geographic regions of Pakistan. The study analyzes the impact of particulate matter (PM2.5 and PM10), nitrogen oxides (NOx), sulfur dioxide (SO_2), and carbon monoxide (CO) on asthma, chronic obstructive pulmonary disease (COPD) and acute respiratory infections by using analysis of air quality data and respiratory health statistics.

The research finds that urban centers like Lahore, Karachi and Islamabad often have air pollution levels well above World Health Organization (WHO) guidelines, which goes hand in hand with an increase in incidence of respiratory illnesses. Health burden is made worse by seasonal variations, socio economic inequalities and restricted access to healthcare, especially among vulnerable groups including children and elderly people as well as low income populations.

Air quality management as an urgent policy, urban planning as a sustainable planning and public health as the intervention measures should be implemented to prevent further air pollution impact on respiratory health, as revealed in this study. The research provides localized evidence to inform local policymakers and stakeholders and support collaborative efforts to better advance and monitor air quality and public health interventions in Pakistan.

INTRODUCTION

Globally, air pollution is known to be a major risk factor for respiratory illness. Rapid urbanization and vehicular emissions, and continued industrial discharges, plus biomass burning lead to high levels of particulate matter (PM), nitrogen oxides (NOx), sulfur dioxide (SO2), and other pollutants in Pakistan. It is made worse by the country's unique geographical and climatic conditions.

Although Pakistan is afflicted by respiratory illnesses like asthma, chronic obstructive pulmonary disease (COPD) and acute respiratory illness, they present a heavy load on Pakistan's healthcare system and this study envisages to study the relationship between respiratory health outcomes due to the level of air pollution in Pakistan by investigating the data on air quality and health statistics in Pakistan. These associations are critical to understanding as a means to developing evidence based policies that improve air quality and public health [1]. Air pollution is a major global health challenge especially in a country such as Pakistan, that is undergoing rapid urbanization, industrialization and population growth and thus aggravating threats to the environment. Air pollution is treated as one of the top 3 killer diseases by the World Health Organization (WHO), which has blamed millions of deaths every year on the impact of its malice. The situation in Pakistan is most alarming as major cities of the country, like Karachi, Lahore and Islamabad, are degrading due to vehicle emissions, industrial discharges, biomass burning and construction activities. In these urban centers, air quality is often over unsafe thresholds, presenting a serious threat to public health. Disorders of respiratory nature such as asthma, chronic obstructive pulmonary disease (COPD), and acute respiratory infection are strongly associated with exposure to air pollution. The burden of these adverse outcomes fall on vulnerable populations, the children, the elderly and otherwise, those with existing health conditions. However, despite the increasing acknowledgement of this problem, few investigations on localized research links between air pollution and respiratory health outcomes have been conducted in Pakistan. However, most of the studies to date have relied on global datasets and regional assessments that cannot capture the country specific socio−environmental dynamics[2], and this study proposes to investigate the effect of air pollution on respiratory health outcomes in Pakistan by analyzing air quality and health records from different parts of the country. Through examining pollutant levels, exposure durations, and health impacts that result, this work aims to supply evidence based insights that can inspire enhancement of public health policies, urban planning, and environmental regulations. The findings will further aid to comprehend the larger ramifications of air contamination on human wellbeing in Pakistan and subside the requirement for collective attempts to defeat its impacts [3].

Methods

Study Design

Within this study, a mixed methods methodology is utilized, whereby the quantitative analysis and investigation of air pollution and health data is combined with qualitative insight from key stakeholders consisting of healthcare professionals and environmental specialists.

Data Collection

For the period of 2015-2023 data on air quality was obtained from monitoring stations in major cities such as Karachi, Lahore Islamabad and Peshawar. PM2.5, PM10, NOx, SO2 and ozone (O3) were the primary pollutants analyzed. Respiratory conditions (e.g., asthma, COPD and ARIs) were the focus for collection of health data from hospital records and public health surveys.

Data Analysis

Correlations between pollutant level measurements, and respiratory health outcomes were assessed through statistical analyses. Seasonal and temporal trends were investigated using time series analysis. Therefore, multivariate regression models were created for controlling the confounding factors, such as age, gender, smoking status, and socioeconomic status.

RESULTS

Air Quality Trends

Analysis and comparison of air quality data in urban area demonstrated that the PM2.5 and PM10 are persistently high (higher than the World Health Organization (WHO guideline values)) in urban areas. There was also seasonal variations with more pollution during the winter because biomass fuels were used more and there was atmospheric inversion.

Health Outcomes

A strong correlation was found between hospital admissions of respiratory illnesses and PM2.5 and PM10. For every 10 $\mu g/m^3$ increase in PM2.5, the relative risk of hospital admissions for asthma and COPD increased by 8% (95% CI: 5-11%). The elderly and young children under five were more likely to contract acute respiratory infections.

Regional Disparities

The air quality was worse, and the respiratory illnesses were higher in cities with high industrial activities and their respective vehicular densities, like Lahore and Karachi, as compared to that in rural areas. Nevertheless, among rural populations indoor air pollution due to biomass burning also accounted for a significantly high contribution to respiratory morbidity.

DISCUSSION

Our findings confirm a robust association between air pollution and respiratory health outcome in Pakistan. There has been a heavy contribution from urbanization and industrialization to this burden of respiratory disease, particularly in children and elderly people. Rural areas continue to face the critical problem of indoor air pollution in need of appropriate and comprehensive air quality management strategies [4].

Strict emission standards, promotion of cleaner technologies and public awareness on efforts to reduce air pollution would be important in efforts to reduce pollution of the air. As important, strengthening of the healthcare infrastructure to care for respiratory illnesses is also necessary. This study reports a strong, concerning relationship between air pollution and respiratory health outcomes in Pakistan. The data show that particulate matter (PM2.5 and PM10), nitrogen oxides (NOx), sulfur dioxide (SO_2) and carbon monoxide (CO) air pollutants act to worsen respiratory health in urban areas with extensive industrial output and car exhaust. Lahore, Karachi and Islamabad, cities, recorded consistently high pollutant concentrations, above safe thresholds recommended by World Health Organization (WHO). Direct linkages from these levels were found with the prevalence of respiratory conditions, such as asthma, chronic obstructive pulmonary disease (COPD) and acute respiratory infections [5].

We found that seasonal variation in pollutant levels, including increased air pollution in winter when temperature inversions occur and/or when biomass is used to heat, increased respiratory health outcomes. These results follow a seasonal trend in keeping with worldwide levels of crime, stressing the importance of tailored interventions in periods of high risk. Groups that were (and are) vulnerable, populations such as children, the elderly and people with underlying respiratory or cardiovascular disease were disproportionately affected too, underscoring the intersection between the environmental and social determinants of health [6].

Several socio economic factors were also identified in the study to intensify the effect of air pollution in respiratory health. Low income and marginalised communities have limited access to healthcare as well as little public awareness concerning the risks of exposure of air pollution, still, lack of enforcement of environmental regulations exacerbate the health burden. Furthermore, urbanisation and industrial development, which have been accelerating economic growth, have been taking place at a very costly price to the environment. Air pollution in Pakistan was mainly attributed to poor urban planning, lack of sufficient public transportation infrastructure and reliance on the use of the fossil fuels [7].

The comparison to previous studies involving similar settings shows consistent trends, underlining the universality of the effect of air pollution on health, and also showing the particular challenges context specific. For example, although there is ample evidence worldwide linking air pollution and respiratory outcomes, Pakistan is further complicated by rapid urbanization, unregulated industrial activity, and dependence on traditional biomass fuels in rural areas [8].

Limitations of this study exist despite the robustness of the findings. A limitation of air quality data availability is the lack of comprehensive nationwide air quality monitoring systems, resulting in sparse data granularity, especially in rural areas where pollution sources are unique to urban settings. The cross sectional nature of study also limits the ability to causally relate air pollution with specific health outcome. The future research should therefore include longitudinal studies and take advantage of advanced exposure assessment methods, such as satellite data and personal air quality monitoring devices, to improve data accuracy and reliability [9].

This study has far reaching implications. Air quality regulations need to be prioritised by policymakers, cleaner technologies promoted and

adequate investments made in public awareness campaigns to buffer the ill health impact of air pollution. Sustainable techniques in urban planning should focus on development of green spaces, encouraging use of public transport and minimization of emissions from manufacturing and vehicular sources, to mitigate the global effect of urban development on the environment. Reducing indoor air pollution through the use of cleaner cooking fuels and improved ventilation can make an enormous difference in reducing respiratory health risks in the community setting, particularly in rural areas[10].

This study concludes with the emphasis on need to make the air pollution a public health priority in Pakistan. The findings provide a foundation for evidence based policy making and interventions to reduce the health burden of air pollution by identifying a link between air pollution and respiratory health outcomes. However, to provide cleaner air and healthy communities in Pakistan, collaborative efforts (both government, industry, and civil society) are required [11].

CONCLUSION

The study emphasizes the necessity of effective air pollution actions in Pakistan. The growing burden of respiratory diseases will require policymakers to give higher priority to air quality improvements. Longitudinal studies should be carried out in future, along with intervention effectiveness in reducing air pollution and the associated health impacts. A key relationship between air pollution and respiratory health outcomes is demonstrated in Pakistan in this study, and it shows the importance of targeting interventions aimed at tackling this major public health challenge. The results show that higher quantities of pollutants like PM2.5, PM10, nitrogen oxide and sulfur dioxide are strongly linked to the increase in the prevalence of respiratory disease, particularly in urban areas with high population density, increased industrial activity and vehicular emissions and those that are densely populated. The findings reveal that individuals that are the most vulnerable, such as children, the elderly, and those with preexisting health conditions disproportionately experience the impacts of air pollution, demonstrating a nexus across environmental and social determinants of health. In addition, the results also show seasonality and socio-economic disparity augment the health impacts of air pollution. Compounding the issue in marginalized communities, are limited access to healthcare, lack of enforcement of environmental regulations, and minimal public awareness. The research that this study provides is essential to understand the localized impacts of air pollution on the people of Pakistan, but and there are many, the limitations of air quality monitoring infrastructure and data availability highlight the need for better research methodologies and longitudinal studies that incorporates the impacts on the different strata of people, in order to address air pollution in Pakistan. Stringent air quality regulations must be implemented and enforced on policymakers, the use of cleaner energy sources has to be encouraged, and sustainable urban planning practices should be prioritized. To reduce indoor and outdoor air pollution risks public awareness campaigns and community level interventions, such as using cleaner cooking fuels or adding improved ventilation, are necessary. The development and maintainability of effective solutions depend on collaborative efforts of government agencies, industries, and civil society organizations in conclusion air pollution is a threat to respiratory health in Pakistan with far reaching impact on the well being of the population and the endurance of urban and rural environs. This research can help stakeholders take informed decisions that will help reduce air pollution and its resultant health impacts and open the door towards a healthier and even more sustainable future.

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