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Abstract: Urbanization and population growth present significant challenges to urban air quality, with adverse implications for public health. This review synthesizes findings from global studies, highlighting the relationship between population density, emissions, and air pollutants such as PM2.5, NOx, and O3. Developed nations show improved air quality due to technological advancements and policies, while developing nations struggle with escalating pollution. Health impacts, including respiratory and cardiovascular diseases, underscore the urgency of mitigation measures. Lessons from COVID-19 lockdowns emphasize innovative strategies like green infrastructure and remote work. Future efforts require periodic policy evaluations and adaptive approaches to sustain urban air quality improvements.

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Introduction

Urbanization and increasing urban population have become a major concern of the 21st century. There is a growing trend of rural-urban migration where the United Nations (2018) estimates that by 2050, 70% of the world's population will be residing in urban areas. Climate change and global warming exacerbate urban air pollution and air quality posing significant health risks to urban dwellers. Carbon Monoxide (CO), Ozone (O3), Nitrogen Oxides (NOx), Sulfur Dioxide (SO2), Volatile Organic Compounds (VOCs), and Particulate Matter (PM) are some of the major air pollutants found in urban centers. With the maximum global population concentrated in urban centers, it is crucial to assess and mitigate urban air pollution. This literature review seeks to understand the global status of urban air quality and its impact on human health. Furthermore, it attempts to answer the following questions:

1. What is the relationship between population density and air quality?
2. What mitigation measures can be implemented to improve urban air quality?

Urban Air Pollution and Population Density

The air quality is comparatively poor in urban settlements than in rural areas. Sicard et al. (2023) compiled urban air quality data for the last two decades of more than 13000 urban cities. Their research findings concluded that globally, $PM_{2.5}$ concentration had declined. However, NO_x and O_3 exposure showed an increasing trend. The urban centers in developed countries showed declining urban air pollutants, while numerous developing countries had positive growth. Improved air quality in urban centers of developed nations can be attributed to technological advancements, better living standards, and investments in cleaner energy among others. On the other hand, developing nations are subjected to worsening urban air quality due to improper urban planning, rapid industrialization, and population explosion (Zhang et. al, 2022). The research by Sicard et al. (2023) covers a larger time frame which can lead to the generalization of numerous important aspects. A study by Krzyzanowski et al. (2014) showed that at least 96% of the populations in the 56 largest global cities are exposed to $PM_{2.5}$ levels exceeding World Health Organization (WHO) Air Quality Guidelines. This study which takes a timeframe of one decade has many precise and concise findings. However, this study takes 56 large cities as its study areas whereas, Sicard et al. (2023) has considered more than 13000 cities in both developed and developing nations. The increasing population density

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in urban centers has implications for urban air pollution. Castells-Quintana et al. (2021) studied air pollution of more than 1200 cities in over 146 countries worldwide and found the following: a) higher population density is associated with significantly lower emissions of both CO_2 and $PM_{2.5}$, b) larger cities tend to display higher emissions per capita, and c) as cities grow in population, they display fewer emissions per capita. Various factors such as energy efficiency in denser cities, carbon footprint, and spatial structure of cities affect urban air quality. Borck and Schrauth (2021) also found similar findings in Germany. Though higher population density has lower emissions of pollutants, aggregation of these pollutants may be large. Understanding the population density in cities can not only help in effective urban planning, but also in formulating strategies to mitigate and adapt to urban air pollution. Globally, exposure to urban air pollution is increasing which has major implications for public health.

Air Pollutants and Human Health

Air pollution can have significant health impacts principally in urban centers where a large number of the population is concentrated. The articles by Sicard et al. (2023), Zhang et al. (2022), Castells-Quintana et al. (2021), and Borck and Schrauth (2021) all highlight how bad air quality has led to millions of premature deaths and exacerbation of existing respiratory and cardiovascular diseases. Furthermore, Castells-Quintana et al. (2021) elaborates on how CO_2 is associated with increased infant mortality and lower life expectancy. This phenomenon is mostly observable in cities of Asian developing nations. Factors such as the lack of health facilities in these cities can further increase the negative externalities of air pollution. While these articles provide basic information on the impact of air pollution on human health, they lack comprehensive study and documentation. Air pollution can give rise to urban heat island (UHI) effect leading to heat strokes. Urban air quality and human health have a positive correlation whereby, if air quality increases, the health of urban dwellers will also relatively improve. Gkatzelis et al. (2021) studied urban air quality during the COVID-19 lockdowns which brought about a newer perspective on air pollution mitigations. During lockdowns, substantial drops in air pollutant levels were observed in various cities. With little to no vehicular emissions, human activities, and industrial emissions, the air quality showed improvements. Further, working from home through virtual conferences such as during the COVID-19 pandemic can be adopted in cities where air pollution mitigations are failing.

Challenges in Urban Air Quality Mitigation and Future Direction

Jonidi et al. (2021) in their study reviewed urban air pollution control policies and strategies. The majority of the policies are focused on the transportation and energy sectors. Furthermore, strategies to reduce CO_2 emissions are supported by providing incentives by the governments. Jonidi's research team overs most of the important aspects of pollution control policies. However, the research lacks the implementation section of all the given policies and strategies. Various elements hamper the improvement of urban air quality. As discussed above, urban population growth can put pressure on existing resources such as more energy demand and transportation. Moreover, climate change and global warming will result in temperature inversion in crowded cities. The mitigation strategies and policies should be reviewed periodically to examine their implementation. In addition, strategists should also add methods such as green spaces and green roofs which will aid in absorbing and reducing air pollutants in urban areas.

Conclusion

This review addresses the relationship between urbanization, air quality, and its profound implications on human health. The synthesis of findings from various studies underscores the global significance of urban air pollution as a critical public health challenge. While developed nations exhibit progress in mitigating air pollutants through technological advancements and stringent policies, the urban centers of developing countries face escalating pollution levels due to rapid

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urbanization and industrial expansion. Population density emerges as a pivotal factor influencing emissions per capita and necessitates proper urban planning strategies. Moreover, the detrimental health effects of air pollution, including respiratory and cardiovascular diseases, underscore the urgency for effective mitigation measures. The COVID-19 lockdowns offer a glimpse of the potential for behavioral shifts and remote work to alleviate air pollution, highlighting the importance of adaptable policies. However, challenges persist in implementing comprehensive strategies, particularly in addressing multifaceted sources of pollution and ensuring equitable access to clean air. Moving forward, continual evaluation and refinement of mitigation policies, alongside innovative approaches such as green infrastructure, are imperative for safeguarding urban air quality and public health in an increasingly urbanized world.

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