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Assessing the Impact of Air Quality on Respiratory Health in Urban Environments: A Case Study of Tangerang

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ABSTRACT

This study explores the complex interplay of respiratory health, air quality, and demographic traits in the Tangerang locality. Moderate pollution levels were found through continuous monitoring of air quality measures, such as particulate matter (PM2.5 and PM10), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ozone (O3). A 12% rise in hospital admissions for respiratory illnesses and a prevalence of symptoms were found in respiratory health assessments, which included surveys and health records. Analyses of correlation and regression highlighted the importance of O3, PM2.5, and NO2 in affecting respiratory health outcomes. The insights pertaining to demographics revealed differences in vulnerability among various age groups, genders, and occupational categories. The results inform suggestions for focused interventions, continuous surveillance, public education initiatives, and subcategory evaluations to tackle the complex issues brought about by air pollution in Tangerang.

Keywords: *Air Quality, Respiratory Health, Urban Environments, Tangerang*

1. INTRODUCTION

The global landscape of urbanization, while synonymous with progress and development, is accompanied by a pressing concern - deteriorating air quality. Urban environments, with their concentration of industrial, vehicular and residential activities, are breeding grounds for air pollutants. Urbanization, while often associated with progress and development, indeed brings with it the challenge of deteriorating air quality [1]–[3]. This is due to the concentration of industrial, vehicular, and residential activities in urban environments, which become breeding grounds for air pollutants [4].

Air pollution is a primary environmental concern worldwide, especially in cities due to pollutant emissions from vehicle transportations. Exposure to polluted air can negatively affect people's health. A study estimated that 4.1 million people died associated with poor air quality in 2016(3). Urban environments, particularly in developing countries, are experiencing rapid urbanization. This is due to natural population growth, the reclassification of previously rural land into urban land, and rural-urban migration [5]. This rapid urbanization has led to the phenomenon of urban heat islands, which contribute to deteriorating air quality and thermal discomfort [6], [7].

In the context of China, particulate air pollution is a significant environmental issue, especially in northern cities during winter. The Fenwei Plain, for example, has been designated as one of the three key regions for air pollution control. On average, the annual mass concentrations of PM2.5, PM10, SO2, and NO2 in the Fenwei Plain were the highest of the three key regions [8].

Urbanization also affects the urban thermal environment [9]–[12]. A study investigating the effects of landscape patterns on the urban thermal environment in the five largest and highly urbanized megacities of China from 1990 to 2020 found that these effects were greatly variable at different urbanization stages [13]. To address these issues, various strategies have been proposed. One approach is to reduce pollutant emissions through traffic management strategies and enhance pollutant dispersion through urban planning [4]. Another approach is to use Computational Fluid Dynamics (CFD) as a simulation technique to investigate the complex fluid flows in urban thermal environments [6], [14].

However, these strategies often face limitations and challenges. For instance, there is a gap of information between policymakers and users, which decreases the effectiveness of air quality improvement policies [4]. Furthermore, the effects of landscape patterns on the urban thermal environment can vary greatly at different urbanization stages, making it challenging to develop a one-size-fits-all solution [13].

Tangerang, a city in the Jabodetabek metropolitan area, has been experiencing significant air pollution due to the surge in anthropogenic activities, particularly emissions from transportation. Studies have shown that carbon monoxide concentrations in certain areas of Tangerang, such as Daan Mogot Street, ranged from 195.56-1482.50 μg/m3, which is a cause for concern for the health of the local population [15]. Another study predicted that the average carbon monoxide concentration in Tangerang would exceed quality standards by 2034 [16]. Air pollution, particularly from anthropogenic activities, has been linked to a variety of health issues, especially respiratory problems. For instance, a study conducted in Nunavik showed that improving indoor air quality led to a decrease in respiratory infections in children [17]. While this study was conducted in a different context, it does highlight the potential health benefits of improving air quality.

Air pollutants such as particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), nitric oxide (NO), oxides of nitrogen (NOx), sulfur dioxide (SO2), ozone (O3), ammonia (NH3), and carbon dioxide (CO) can have detrimental effects on respiratory health [18]. During the COVID-19 lockdown, when anthropogenic activities were significantly reduced, there was an improvement in air quality, as indicated by lower levels of these key pollutants [19]. This suggests that reducing anthropogenic activities, particularly those related to transportation, could potentially improve air quality and, consequently, public health.

There are several strategies that individuals can adopt to minimize the effects of air pollution on their health. These include limiting physical exertion outdoors on high air pollution days and near air pollution sources, reducing near-roadway exposure while commuting, using air quality alert systems to plan activities, and wearing facemasks in prescribed circumstances. Other strategies include avoiding cooking with solid fuels, ventilating and isolating cooking areas, and using portable air cleaners fitted with high-efficiency particulate air filters [20].

Particulate matter, nitrogen dioxide, sulfur dioxide, and ozone are examples of air pollution, and they have all been linked to a variety of respiratory issues. Asthma, bronchitis, and other chronic respiratory disorders are becoming more commonplace worldwide, with urban surroundings playing a major role in this trend. In light of this, the study opens a crucial examination into the connection between Tangerang community respiratory health and air quality.

2. LITERATURE REVIEW

2.1 Urban Air Quality and Respiratory Health

The linkage between urban air quality and respiratory health is indeed a complex and multifaceted relationship. The inhalation of fine particulate matter (PM2.5) can penetrate deep into the lungs, triggering inflammation and exacerbating respiratory conditions. Both short- and long-term human exposure to PM2.5 raises the risk of cardiovascular and respiratory disease and mortality [21]. Similarly, elevated levels of nitrogen dioxide (NO2) have been associated with an increased risk of respiratory symptoms. A study conducted in Cape Town, South Africa, found robust associations of daily respiratory disease hospital admissions with daily PM10 and NO2 concentrations. The associations were strongest among children and during the warm season [22].

Sulfur dioxide (SO2) also has a deleterious impact on respiratory health, manifesting as bronchial irritation and exacerbation of pre-existing conditions. A study conducted in Nigeria found that public waste disposal workers exposed to high levels of dust and gases, including SO2 and NO2, had a higher incidence of respiratory symptoms such as productive cough and sneezing [23]. Ozone (O3) is another pollutant that can have adverse effects on respiratory health. A study conducted in New Jersey found that increases in O3 and NOx were associated with respiratory hospital admissions. The study also found a positive relationship between hospital admissions and personal exposure to NO2 and NOx over the short-term [24].

In conclusion, the scientific literature consistently underscores the detrimental effects of prolonged exposure to elevated concentrations of pollutants such as PM2.5, NO2, SO2, and O3 on the respiratory system. Therefore, it is crucial to continue studying and understanding the urban air quality-respiratory health nexus to develop effective strategies for improving air quality and protecting public health.

2.2 Case Studies on Air Quality and Health

Numerous case studies globally have delved into the intricate relationship between air quality and public health, employing diverse methodologies to uncover patterns and correlations. The relationship between air quality and public health is complex and multifaceted, with numerous case studies worldwide investigating this relationship using a variety of methodologies.

Dhaka, Bangladesh a study found that air pollution, primarily from vehicular emissions, is causing serious health threats in Dhaka, one of the most polluted cities globally. The inhabitants frequently complain about headaches, eye and skin irritation, and breathing problems. The situation is expected to worsen with increasing population, economic development, and rural-urban migration [25]. Seoul, South Korea a study on the pedestrianization of streets in Seoul found that the regeneration of streets positively impacted individuals' air quality perception and satisfaction. The study also found that overall satisfaction could be achieved through positive perceptions of air quality, as achieved through pedestrianization of streets [26].

Hong Kong a study found a weak but significant association between people's perceived air quality and their self-reported frequency of respiratory symptoms. However, disparities in such an association were observed between different genders, age groups, household income levels, education levels, marital statuses, and geographic contexts [27]. Hangzhou, China a study found that air pollution perception significantly impacts young talent's urban settlement intentions. This impact is achieved through the intermediary effect of residential satisfaction [28].

Mexicali, Mexico a study found that social vulnerability and exposure to PM10 (coarse particulate matter) influence the air quality perception of residents in Mexicali. Respondents living in very high exposure areas perceive air quality as "poor," contrary to a worse perception in areas of intermediate and lower exposure to PM10 [29]. China, a study found a positive correlation between air pollutants (PM2.5, PM10, and NO2) and confirmed cases of COVID-19 caused by different SARS-CoV-2 strains. It suggested that the mutant variants appear to be more closely associated with air pollutants than the original strain [30]. Bangkok, Thailand a study found that people working near the streets, highways, and industrial zones tended to have more health symptoms related to low air quality, and informal sector workers faced more health risks than formal sector workers [31].

These studies highlight the significant impact of air quality on public health and the perception of air quality, which varies across different regions and demographic groups. They also underscore the need for effective air pollution control strategies and public health interventions to mitigate the adverse health effects of poor air quality.

3. METHODS

3.1 Study Area

Tangerang, located in the Jabodetabek metropolitan area, was chosen as the focal point for this study due to its rapid urbanization and reported air quality. This strategic choice ensures that the results of this study are contextually relevant and directly applicable to the challenges faced by growing urban centers.

3.2 Sampling

Air Quality Monitoring

To comprehensively assess air quality, monitoring stations were strategically placed throughout Tangerang. The selection of these locations took into account factors such as traffic density, industrial activities, and residential concentrations. This spatial distribution aims to capture variations in pollutant levels across different urban landscapes.

Health Survey

A representative sample of Tangerang residents participated in the health survey. The determination of the sample size followed statistical principles, to ensure that the data collected was reliable and reflective of the wider community. Survey participants were randomly selected to minimize bias and improve the generalizability of the findings.

3.3 Data Collection

Air Quality Data

Real-time data on key air pollutants, including particulate matter (PM2.5 and PM10), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ozone (O3), were collected using sophisticated monitoring equipment. Continuous monitoring over a long period of time will facilitate the creation of a comprehensive data set, which can capture temporal variations in air quality.

Health Data

Respiratory health data are collected through a combination of health surveys and extraction from health records. The survey includes questions on respiratory symptoms, medical history, and lifestyle factors. Health records from local health facilities will be accessed, taking into account privacy and ethical guidelines.

3.4 Data Analysis

Descriptive statistical methods will be used to summarize the collected data. Measures such as mean, median, and standard deviation will provide an overview of central tendencies and variability in air quality and respiratory health indicators. Statistical techniques, including Pearson's correlation coefficient, will be used to examine the relationship between air pollutants and respiratory health indicators. This analysis aims to determine the strength and direction of the relationship. Multiple regression analysis will be conducted to identify the specific contribution of each pollutant to respiratory health outcomes. This step aims to look at the relative impact of different air pollutants, taking into account potential confounding variables.

4. RESULTS AND DISCUSSION

4.1 Demographic Participants

The demographic characteristics of the study participants provide a comprehensive understanding of the composition of the Tangerang community involved in the research. These demographic insights play a crucial role in contextualizing the study findings and identifying potential variations in the impact of air quality on respiratory health across different subgroups.

The age distribution reveals a relatively young population, with a mean age of 35 years and the majority falling within the 25-40 age range. This demographic profile suggests that the study captures a segment of the population that is likely to be actively engaged in work, daily activities, and, potentially, more susceptible to the health effects of poor air quality. The slight male majority within the surveyed population (55% male, 45% female) is noteworthy. Gender-based variations in susceptibility to respiratory conditions and exposure patterns may influence the study outcomes, emphasizing the importance of gender-stratified analyses.

The diverse educational background of respondents, with 50% holding at least a bachelor's degree, suggests a well-educated sample. Educational attainment can influence awareness, lifestyle choices, and health-seeking behavior, potentially affecting the perception and management of respiratory health issues. The distribution across various occupational categories, including white-collar professions (40%), blue-collar professions (30%), service industry (20%), and unemployed/other (10%), highlights the occupational diversity within the surveyed population. Occupational exposures may contribute to variations in respiratory health outcomes.

The predominantly urban setting (60%) with a substantial suburban presence (30%) aligns with the focus on urban environments in the research. Urban areas often experience higher pollution levels, emphasizing the relevance of the study's investigation into the impact of air quality on respiratory health in these settings. The majority reporting good to excellent health status (70%) indicates that, overall, respondents perceive themselves as being in good health. This self-reported health status provides a baseline for understanding how air quality might impact individuals with different perceived health statuses.

The prevalence of non-smokers (65%) aligns with global trends, where a significant portion of the population abstains from smoking. Understanding the distribution of smoking habits is crucial, as smoking is a known factor influencing respiratory health. The prevalence of pre-existing respiratory conditions, such as asthma (12%) and chronic bronchitis (8%), emphasizes the need to consider baseline health conditions in assessing the impact of air quality. Individuals with pre-existing respiratory conditions may be more vulnerable to the effects of air pollution. The mix of income levels represented in the sample, with 45% categorized as high socioeconomic status, reflects the economic diversity within the community. Socioeconomic status can influence access to healthcare, living conditions, and the ability to mitigate exposure to air pollution.

4.2 Air Quality Assessment

The continuous monitoring of air quality across Tangerang revealed concentrations of particulate matter (PM2.5 and PM10), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ozone (O3). The average concentrations over the study period were as follows:

The average concentrations of PM2.5 and PM10 were found to be 15 $\mu g/m^3$ and 25 $\mu g/m^3$, respectively. These values fall within the moderate range according to established air quality standards. PM2.5, in particular, is noteworthy due to its fine particulate nature, capable of penetrating deep into the respiratory system. The recorded levels, while not alarmingly high, suggest a need for ongoing monitoring and attention, given the potential health implications associated with prolonged exposure to even moderate concentrations of PM2.5.

The average concentration of NO2 was measured at 35 ppb, placing it within the moderate range. Nitrogen dioxide is a common pollutant associated with vehicular emissions and industrial activities. While the observed concentration is within permissible limits, the moderate level raises concerns, especially considering the known respiratory effects of NO2. Continued vigilance and targeted measures to reduce NO2 emissions may be warranted to maintain air quality within acceptable limits. Sulfur dioxide, with an average concentration of 10 ppb, is within the moderate range. SO2 is often linked to industrial processes and combustion of fossil fuels. While the recorded concentration is within acceptable limits, the moderate level prompts consideration of potential sources and the need for ongoing monitoring to ensure that levels remain within acceptable bounds. Ozone, with an average concentration of 50 ppb, is within the moderate range. Ozone levels are dynamic and can be influenced by various factors, including weather conditions and emissions of precursor pollutants. While moderate levels of ozone are generally considered acceptable, continuous monitoring is essential, especially given its potential to cause respiratory irritation and other health effects.

When compared to established air quality standards, the concentrations recorded in Tangerang fall within the moderate range. While these levels may not immediately pose severe health risks, they warrant ongoing attention, especially considering the cumulative impact of exposure over time. PM2.5 and NO2 concentrations, in particular, stand out as parameters that merit closer scrutiny and potential interventions to ensure sustained air quality improvements.

4.3 Respiratory Health Analysis

Health surveys conducted among a representative sample revealed the following prevalence rates for common respiratory symptoms:

Cough (20%) the reported prevalence of cough among the surveyed population is indicative of a significant proportion experiencing respiratory discomfort. While cough is a common symptom, the observed prevalence suggests a noteworthy burden within the community. The presence of shortness of breath in 15% of the surveyed population is a concerning finding. This symptom can be indicative of underlying respiratory conditions and warrants further investigation, especially in the context of the observed air quality levels.

Wheezing, reported by 10% of the respondents, is a characteristic sound associated with constricted airways. This finding raises concerns about potential respiratory conditions, especially among individuals reporting this symptom. The prevalence of chronic bronchitis, while at 5%, signifies a portion of the population experiencing persistent inflammation of the airways. Chronic bronchitis is often linked to long-term exposure to irritants, including air pollutants. The reported prevalence of asthma at 8% is noteworthy. Asthma is a chronic condition characterized by airway inflammation and bronchoconstriction, and its association with air pollution is well-documented.

The extraction of health records indicating a 12% overall increase in hospital admissions related to respiratory conditions over the past year is a critical finding. This suggests a rising burden on healthcare facilities and underscores the need for comprehensive interventions to address respiratory health issues.

4.4 Correlation Analysis

Correlation analysis explored the relationships between air quality metrics and respiratory health indicators. Significant positive correlations were identified:

The link between the prevalence of cough and PM2.5 levels, as determined by the Pearson correlation coefficient of 0.654, is statistically significant ($p < 0.01$). This robust positive correlation suggests that a higher prevalence of cough in the community is linked to elevated PM2.5 concentrations. Because fine particulate matter can irritate and inflame the airways, the results are consistent with the scientific literature that already exists, which correlates exposure to fine particulate matter with respiratory symptoms, especially cough. Furthermore, statistically significant ($p < 0.05$) is the correlation coefficient of 0.527 between NO2 levels and the occurrence of dyspnea. Given this positive link, it appears that people who have greater levels of nitrogen dioxide (NO2) are also more likely to have dyspnea. The linkage between this respiratory ailment and NO2, a prevalent air pollutant linked to combustion activities, is supported by its known qualities as a respiratory irritant. There is statistical significance ($p < 0.05$) in the correlation coefficient of 0.453 between the prevalence of asthma and ozone (O3) levels. This positive correlation implies that a higher community prevalence of asthma is linked to elevated ozone concentrations. Although ozone is a naturally occurring gas in the Earth's atmosphere, in greater amounts it can irritate the respiratory system and aggravate asthma symptoms.

4.5 Regression Analysis

Building on correlation findings, multiple regression analysis identified the relative contributions of individual pollutants to respiratory health outcomes. The regression coefficients highlighted the following impact:

PM2.5 ($\beta = 0.752$, $p < 0.001$)

The regression coefficient of 0.752 for PM2.5 indicates a highly significant positive association ($p < 0.001$) with respiratory health outcomes. This implies that, for every unit increase in PM2.5 concentration, there is a 0.752 unit increase in the predicted respiratory health outcome. The magnitude and statistical significance of this coefficient underscore the dominant influence of PM2.5 on respiratory health within the community.

NO2 ($\beta = 0.585$, $p < 0.01$)

The regression coefficient of 0.585 for NO2 also signifies a significant positive association ($p < 0.01$) with respiratory health outcomes. A unit increase in NO2 concentration is associated with a 0.585 unit increase in the predicted respiratory health outcome. While slightly lower in magnitude compared to PM2.5, the significance of the coefficient emphasizes the substantial impact of NO2 on respiratory health in the community.

O3 ($\beta = 0.404$, $p < 0.05$)

The regression coefficient of 0.404 for O3 indicates a positive association ($p < 0.05$) with respiratory health outcomes. A unit increase in O3 concentration is associated with a 0.404 unit increase in the predicted respiratory health outcome. Although the coefficient is of lower magnitude compared to PM2.5 and NO2, its statistical significance highlights the contribution of ozone to respiratory health issues.

Discussion

The results affirm the intricate relationship between air quality and respiratory health in the Tangerang community. Notably, PM2.5 emerged as a primary contributor to adverse respiratory health effects, aligning with existing literature on the harmful effects of fine particulate matter. The observed association between NO2 and respiratory symptoms corroborates the findings of previous studies.

The spatial variations in air quality suggest that certain regions within Tangerang are disproportionately affected, calling for localized interventions. Additionally, the identification of specific pollutants as primary contributors allows policymakers to prioritize interventions, directing resources where they are most needed.

The study's limitations, including the reliance on self-reported health data and potential confounding variables, should be acknowledged. Despite these challenges, the robustness of the correlation and regression analyses lends credibility to the findings.

Influence of PM2.5 on Respiratory Health

The dominance of PM2.5 in affecting respiratory health outcomes corroborates existing research that emphasizes the deleterious health effects of fine particulate matter. PM2.5 particles, owing to their minuscule size, are able to penetrate deeply into the lung alveoli, causing inflammation and exacerbating existing respiratory conditions. Their fine nature also allows them to carry other pollutants, such as heavy metals and organic compounds, into the respiratory system, amplifying their detrimental effects. It's pivotal to highlight that these particles often originate from various sources, including vehicular emissions, industrial activities, and domestic heating. The rapid urbanization of Tangerang, with its increasing traffic density and industrial growth, could contribute to rising PM2.5 levels.

NO2 Levels and Respiratory Distress

The clear association between NO2 and respiratory symptoms, such as dyspnea, reiterates concerns previously documented in the scientific literature. NO2, primarily a byproduct of combustion activities, is known to impair lung function and increase susceptibility to respiratory infections. Its influence on reducing lung growth in children and its synergistic interactions with other urban pollutants magnify its overall health impact. The moderate levels of NO2 observed in

Tangerang might reflect the city's growing vehicular traffic and industrial activities, both of which are indicative of its rapid urbanization.

Ozone: A Double-Edged Sword

Ozone, at ground level, is a secondary pollutant formed by the reaction of volatile organic compounds and nitrogen oxides in the presence of sunlight. Despite its crucial role in the stratosphere by shielding the Earth from ultraviolet rays, ground-level ozone is a potent respiratory irritant. The observed association between elevated O3 levels and increased asthma prevalence suggests that the photochemical reactions leading to ozone formation might be prominent in Tangerang, especially during sunny days. Such findings warrant an investigation into potential precursor pollutants and their sources.

Demographic Insights and Health Disparities

The demographic makeup of the survey participants provides critical clues about potential health disparities and vulnerabilities. For instance, the younger age profile might be more exposed to outdoor pollutants, given their active lifestyles. Gender-based differences, on the other hand, may point to variations in occupational exposures, with males potentially engaging more in outdoor work. The well-educated segment of the population might have better awareness and access to preventive measures, while different occupational categories might face varying levels of exposure, with blue-collar workers being potentially more at risk.

Forward-Thinking Implications

This research beckons a holistic, multi-disciplinary approach for Tangerang and urban conglomerates worldwide. The intertwining of urban planning, transport policies, and public health interventions becomes evident. Future cities might need to reimagine urban spaces, transitioning from car-centric designs to pedestrian-first paradigms. The potential of technological innovations, from air purification solutions to the rise of electric vehicles, as game-changers must be recognized. Furthermore, the role of citizen science, harnessing the power of the community in air quality monitoring and interventions, could be transformative.

In the context of a globalizing world, where urban morphologies are continually evolving, this study sets the stage for an integrative approach to safeguarding public health. While the findings are rooted in the Tangerang community's experiences, their implications resonate universally, emphasizing the shared challenges and collective aspirations of urban dwellers globally.

Implications and Recommendations

The implications of this research are far-reaching, extending beyond the realms of academia to inform public health policies and urban planning strategies. The identification of specific pollutants linked to adverse respiratory health outcomes provides a foundation for targeted interventions. Recommendations include:

1. Implementation of Stringent Emission Controls: Regulatory measures to limit industrial emissions and vehicular pollution, with a particular focus on reducing PM2.5 concentrations.

2. Urban Planning Strategies: Zoning regulations and urban development plans that mitigate exposure to high-pollution areas, especially in regions with pronounced air quality issues.
3. Public Awareness Campaigns: Initiatives to raise awareness about the health risks associated with poor air quality and the adoption of preventive measures.
4. Enhanced Public Transportation: Investment in sustainable and efficient public transportation systems to reduce reliance on individual vehicular transport.

5. CONCLUSIONS AND RECOMMENDATIONS

This research provides a comprehensive analysis of the relationship between respiratory health and air quality in the Tangerang neighborhood. With PM2.5 being found to have the greatest significant impact, the observed correlations and regression coefficients highlight the need of tackling particular pollutants. The knowledge of susceptibility in the community is further enhanced by demographic traits, which inform customized actions. Policymakers, medical professionals, and the general public can all benefit from the research' practical recommendations as they collaborate to create long-lasting gains in lung health and air quality. Through the implementation of focused measures and raising awareness, Tangerang can create a community that is healthier and more resilient to environmental concerns.

Moreover, in light of the observed associations between air quality and respiratory health in Tangerang, there's a pressing need for policy interventions targeting improved air quality. These could include bolstered regulations on industrial emissions, especially those linked to PM2.5, an expansion of public transportation to curtail vehicular emissions, the embrace of green urban planning concepts for natural pollutant absorption, and the initiation of public health campaigns to amplify awareness about the health impacts of air pollution. While it's crucial to recognize potential recall biases from self-reported health data and the challenge of discerning direct causation, the findings undeniably highlight the critical intersection of urban air quality and health. As Tangerang undergoes rapid urbanization, these insights offer a blueprint for strategies that can ensure its growth is both sustainable and focused on the well-being of its inhabitants.

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