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INFLUENCE OF AIR POLLUTION ON RESPIRATORY MORBIDITY IN INDUSTRIAL REGIONS

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Abstract: Background: Rapid industrialization has significantly altered air quality profiles in urban centers, leading to adverse health outcomes. This study investigates the correlation between key air pollutants ($PM_{2.5}$, PM_{10}, NO_2, SO_2) and the prevalence of respiratory diseases in industrial zones compared to non-industrial control areas. Methods: A retrospective ecological study was conducted utilizing data from 2019 to 2023. Air quality data was obtained from monitoring stations, while respiratory morbidity data (COPD, asthma, acute respiratory infections) was collected from regional health bureaus. Statistical analysis involved Pearson correlation coefficients and multiple regression models. Results: The study revealed a statistically significant correlation between elevated levels of particulate matter ($PM_{2.5}$) and hospital admissions for acute asthma exacerbations ($r = 0.72$, $p < 0.01$). Residents in the industrial zone exhibited a 35% higher incidence of chronic respiratory conditions compared to the control group. Conclusion: There is a direct, quantifiable link between industrial air pollution and respiratory morbidity. The findings necessitate urgent policy interventions, including stricter emission controls and the establishment of green buffer zones to mitigate public health risks.
Keywords: Air pollution, respiratory morbidity, industrial hygiene, particulate matter, asthma, COPD, environmental epidemiology.

SANOAT MINTAQALARIDA HAVO IFLOSLANISHINING NAFAS OLISH KASALLANISHIGA TA’SIRI

Annotatsiya: Kirish: Sanoatlashuvning tezlashishi shaharlarda havo sifati profilini sezilarli darajada o‘zgartirib, salbiy oqibatlarga olib kelmoqda. Ushbu tadqiqot asosiy havo ifloslantiruvchilari ($PM_{2.5}$, PM_{10}, NO_2, SO_2) va nafas olish kasalliklarining tarqalishi o‘rtasidagi bog‘liqlikni sanoat va nazorat hududlarini taqqoslash orqali o‘rganadi. Usullar: 2019–2023 yillarni qamrab olgan retrospektiv ekologik tadqiqot o‘tkazildi. Havo sifati ma’lumotlari monitoring stansiyalaridan, kasallanish ko‘rsatkichlari (O‘SOK, astma, o‘tkir respirator infeksiyalar) esa hududiy sog‘liqni saqlash bo‘limlaridan olindi. Statistik tahlilda Pearson korrelyatsiyasi va ko‘p o‘lchovli regressiya modellaridan foydalanildi. Natijalar: Tadqiqot muallaq zarrachalar ($PM_{2.5}$) darajasining oshishi va o‘tkir astma xuruji bilan shifoxonaga yotqizishlar o‘rtasida statistik ishonchli bog‘liqlikni aniqladi ($r = 0.72$, $p < 0.01$). Sanoat zonasida yashovchi aholida surunkali nafas olish kasalliklari nazorat guruhiga nisbatan 35% ga yuqori ekanligi ma’lum bo‘ldi. Xulosa: Sanoat havosi ifloslanishi va nafas olish kasallanishi o‘rtasida to‘g‘ridan-to‘g‘ri bog‘liqlik mavjud. Natijalar havoga chiqarilayotgan chiqindilarni qat’iy nazorat qilish va aholi salomatligini himoya qilish uchun yashil bufer zonalarini tashkil etish kabi shoshilinch choralarni talab qiladi.
Kalit so‘zlar: Havo ifloslanishi, nafas olish kasallanishi, sanoat gigiyenasi, muallaq zarrachalar, astma, O‘SOK, atrof-muhit epidemiologiyasi.

ВЛИЯНИЕ ЗАГРЯЗНЕНИЯ ВОЗДУХА НА РЕСПИРАТОРНУЮ ЗАБОЛЕВАЕМОСТЬ В ПРОМЫШЛЕННЫХ РЕГИОНАХ

Аннотация: Введение: Быстрая индустриализация существенно изменила профиль качества воздуха в городских центрах, что привело к негативным последствиям для

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здоровья. В данном исследовании изучается корреляция между основными загрязнителями воздуха ($PM_{2.5}$, PM_{10}, NO_2, SO_2) и распространенностью респираторных заболеваний в промышленных зонах по сравнению с контрольными непромышленными районами. Методы: Было проведено ретроспективное экологическое исследование с использованием данных за 2019–2023 годы. Данные о качестве воздуха были получены со станций мониторинга, а данные о респираторной заболеваемости (ХОБЛ, астма, острые респираторные инфекции) — из региональных бюро здравоохранения. Статистический анализ включал коэффициенты корреляции Пирсона и модели множественной регрессии. Результаты: Исследование выявило статистически значимую корреляцию между повышенным уровнем взвешенных частиц (PM2.5) и госпитализацией по поводу обострений астмы ($r = 0,72$, $p < 0,01$). У жителей промышленной зоны заболеваемость хроническими респираторными болезнями была на 35% выше по сравнению с контрольной группой. Заключение: Существует прямая количественная связь между промышленным загрязнением воздуха и респираторной заболеваемостью. Результаты требуют принятия срочных мер, включая более строгий контроль выбросов и создание зеленых буферных зон для снижения рисков для здоровья населения.

Ключевые слова: Загрязнение воздуха, респираторная заболеваемость, промышленная гигиена, взвешенные частицы, астма, ХОБЛ, экологическая эпидемиология.

INTRODUCTION

Air pollution remains one of the most pressing environmental health challenges of the 21st century, posing a severe threat to global public health and economic stability. The rapid pace of urbanization and industrial expansion has fundamentally altered the atmospheric composition in many developing regions. According to the World Health Organization (WHO), approximately 99% of the global population breathes air that exceeds WHO guideline limits and contains high levels of pollutants, with low- and middle-income countries suffering from the highest exposures. This environmental crisis contributes to millions of premature deaths annually, primarily due to stroke, heart disease, chronic obstructive pulmonary disease (COPD), lung cancer, and acute respiratory infections.

Industrial regions, characterized by a high density of manufacturing plants, thermal power stations, chemical refineries, and heavy logistical traffic, represent "hotspots" where pollutant concentrations frequently exceed national and international safety guidelines. In these areas, the emission of particulate matter (PM), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and volatile organic compounds (VOCs) is constant and intense. Unlike general urban pollution, which is often traffic-related, industrial pollution includes a more complex mix of toxic heavy metals and chemical byproducts, potentially leading to more severe health outcomes.

The respiratory system, being the primary interface between the internal biological environment and the external atmosphere, is particularly vulnerable to airborne toxicants. Inhalation is the most direct route of exposure; thus, the lungs are the first organs to suffer from the cytotoxic and inflammatory effects of pollutants. While the general link between pollution and health is well-established in global literature, specific epidemiological data concerning the magnitude of impact in rapidly developing industrial zones remains critical for local policy-making. There is often a gap in data regarding how specific industrial profiles (e.g., chemical vs. metallurgical) correlate with local disease patterns.

This study aims to quantify the influence of key industrial pollutants on the morbidity rates of respiratory diseases. By specifically comparing a densely industrialized district with a cleaner, rural control zone, this research seeks to isolate the "industrial factor" in respiratory health degradation and provide an evidence base for targeted public health interventions.

LITERATURE REVIEW

The association between ambient air pollution and respiratory health has been the subject of

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extensive research over the past few decades, evolving from simple association studies to complex toxicological and mechanistic investigations.

Particulate Matter ($PM_{2.5}$ and PM_{10}) and Alveolar Damage Research consistently identifies Particulate Matter (PM) as a primary driver of respiratory pathology. Pope et al. (2002) demonstrated in a landmark study that long-term exposure to fine particulate matter ($PM_{2.5}$) is significantly associated with an increased risk of cardiopulmonary mortality. The aerodynamic diameter of these particles is crucial; PM10 affects the upper airways, while $PM_{2.5}$ can penetrate deep into the alveolar region, crossing the blood-gas barrier. This deep penetration triggers oxidative stress and systemic inflammation, not just localized lung damage. Recent studies by Xing et al. (2016) have further elucidated that heavy metals (such as lead, arsenic, and cadmium) adsorbed onto PM surfaces in industrial areas exacerbate this inflammatory response, leading to the remodeling of airway tissues and the development of Chronic Obstructive Pulmonary Disease (COPD).

Gaseous Pollutants (NO_2 and SO_2) - Nitrogen dioxide (NO2) and Sulfur dioxide (SO2), common byproducts of fossil fuel combustion in industrial processes, act as potent respiratory irritants. A meta-analysis by Anderson et al. (2013) highlighted strong evidence linking short-term NO_2 exposure to increased hospital admissions for asthma, particularly in children. NO_2 is known to increase bronchial responsiveness and allergic susceptibility. Similarly, SO_2 exposure causes immediate bronchoconstriction and increases susceptibility to respiratory infections by impairing the mucociliary clearance mechanism—the lung's primary defense system against pathogens. In industrial zones with coal-fired power plants, SO_2 remains a dominant risk factor for chronic bronchitis.

Mechanisms of Pathogenesis - Oxidative Stress and Inflammation The underlying biological mechanisms linking air pollution to respiratory disease are complex. The leading hypothesis involves the generation of Reactive Oxygen Species (ROS). When pollutants enter the respiratory tract, they induce the production of free radicals, overwhelming the lung's antioxidant defenses. This state of "oxidative stress" activates inflammatory pathways (such as the NF-kB pathway), leading to the release of cytokines (IL-6, TNF-alpha). This chronic inflammation results in tissue damage, airway hyper-responsiveness, and a decline in lung function over time (Brunekreef & Holgate, 2002).

Synergistic Effects in Industrial Zones - While individual pollutants are harmful, the "cocktail effect" found in industrial regions is of particular concern. Studies in industrial hubs of developing nations suggest that the combined effect of gaseous pollutants and particulate matter is greater than the sum of their individual effects (Kampa & Castanas, 2008). For instance, the presence of SO_2 can facilitate the deep absorption of $PM_{2.5}$ into lung tissues. Furthermore, industrial zones often have unique microclimates that can trap pollutants near the ground level, prolonging exposure duration for local residents. Despite this knowledge, there is a need for more localized studies that account for specific industrial profiles and their specific impact on local morbidity rates, which this study addresses.

MATERIALS AND METHODS

Study Design and Area A retrospective ecological study was conducted covering a 5-year period (2019–2023). The study area was divided into two distinct zones: 1) Zone A (Industrial) - A district containing a chemical processing plant and a thermal power station. Population: ~50,000. 2) Zone B (Control): A rural agricultural district located 40 km upwind from Zone A, with no major industrial facilities. Population: ~45,000.

Environmental Data - Daily average concentrations of $PM_{2.5}$, PM_{10}, NO_2, and SO_2 were obtained from automated air monitoring stations located in the geometric centers of both zones.

Health Data - Anonymized aggregate data on hospital admissions and outpatient visits for ICD-10 codes J40-J47 (Chronic lower respiratory diseases) and J00-J22 (Acute respiratory infections) were collected from the regional health bureau.

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Statistical Analysis - Data were analyzed using SPSS version 26.0. The Air Quality Index (AQI) was calculated based on national standards. Comparative analysis was performed using T-tests to determine differences in pollutant mean values. Pearson correlation analysis was utilized to assess the relationship between pollutant concentrations and monthly morbidity rates. A p-value of <0.05 was considered statistically significant.

RESULTS

Air Quality Assessment The analysis of environmental monitoring data revealed a stark contrast between the two zones. As shown in Table 1, Zone A consistently exceeded WHO recommended limits for all measured pollutants.

Table 1: Annual Mean Concentration of Pollutants (µg/m3) (2019–2023)

Pollutant	Zone A (Industrial)	Zone B (Control)	WHO Guideline (Annual)	Difference (%)
$PM_{2.5}$	48.2 ± 5.4	12.1 ± 2.1	5	+298%
PM_{10}	75.6 ± 8.2	24.3 ± 3.5	15	+211%
NO_2	52.1 ± 4.1	14.2 ± 1.8	10	+266%
SO_2	35.4 ± 6.3	5.1 ± 0.9	40 (24h)*	+594%

Note: Data represents 5-year averages. Standard deviation is indicated.

Respiratory Morbidity Analysis - Morbidity rates were significantly higher in the industrial zone. Table 2 illustrates the incidence of key respiratory conditions per 1,000 population.

Table 2: Incidence of Respiratory Diseases (per 1,000 population)

Disease Category	Zone A (Industrial)	Zone B (Control)	Relative Risk (RR)	P-value
Acute Upper Respiratory Infections	310.5	185.2	1.67	<0.01
Bronchial Asthma	42.8	18.4	2.32	<0.001
COPD	28.6	9.1	3.14	<0.001
Allergic Rhinitis	115.3	45.6	2.52	<0.01

Correlation Analysis - A strong positive correlation was observed between specific pollutants and hospital admissions. PM2.5 showed the strongest correlation with asthma exacerbations (r = 0.72), while SO_2 levels correlated strongly with chronic bronchitis diagnoses (r = 0.68).

DISCUSSION

The results of this study unequivocally confirm that proximity to industrial pollution sources acts as a major determinant of respiratory health. The 3.14 Relative Risk (RR) for COPD in Zone A suggests that residents in the industrial area are more than three times as likely to develop obstructive pulmonary diseases compared to their rural counterparts.

The high levels of $PM_{2.5}$ in Zone A are likely attributable to combustion processes and fugitive dust from industrial operations. The correlation analysis supports the hypothesis that fine particulate matter acts as a trigger for acute asthma attacks, likely due to its ability to induce airway inflammation and oxidative stress.

Furthermore, the significant difference in Allergic Rhinitis cases suggests that industrial pollutants may be acting as adjuvants, increasing the sensitization of the airway mucosa to common allergens. These findings align with the "adjuvant effect" theory proposed in recent immunological studies.

One limitation of this study is the inability to fully control for individual confounding factors such as smoking history and indoor air pollution (e.g., cooking fuels), although the large sample size and demographic similarities between the zones help mitigate this bias.

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CONCLUSION

This study provides compelling evidence of the detrimental impact of industrial air pollution on respiratory morbidity. The data indicates that current emission control measures in the studied industrial region are insufficient to protect public health.

There is a robust statistical link between industrial activity and the prevalence of both acute and chronic respiratory diseases.

Vulnerable Populations: The high incidence of asthma suggests that children and the elderly in industrial zones are facing disproportionate health risks.

$PM_{2.5}$ and NO_2 appear to be the most critical drivers of morbidity in this specific industrial context.

RECOMMENDATIONS

Mandatory installation of advanced electrostatic precipitators and desulfurization units in local factories.

Implementation of a strict "Green Belt" buffer zone of at least 2 km between industrial facilities and residential settlements.

Establishment of specialized respiratory screening programs for residents living within a 10 km radius of the industrial zone.

Introduction of a real-time air quality alert system to advise vulnerable residents to stay indoors during high-pollution days.

Future research should focus on the long-term longitudinal tracking of pediatric cohorts in these regions to understand the impact of early-life exposure on lung development.

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