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# The Role of Environmental Pollutants in Exacerbating Pediatric Asthma: A Health Security, Epidemiological, and Health Information Perspective

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**Abstract**

This study explores the growing prevalence of pediatric asthma in Saudi Arabia, focusing specifically on Jeddah city, and examines the significant role of environmental pollutants in exacerbating the condition. Asthma, a chronic inflammatory respiratory disease, affects millions of children worldwide and is influenced by genetic and environmental factors. This study surveyed 400 children diagnosed with asthma and their caregivers in Jeddah, highlighting household allergens like dust mites and environmental pollutants such as vehicle emissions, industrial fumes, and airborne dust particles, as key contributors to the exacerbation of asthma symptoms. Findings indicate that children living in areas with high pollution levels, including heavy traffic zones and industrial vicinities, exhibit increased asthma prevalence and severity. Additionally, the study highlights the influence of sociodemographic factors, such as parental education and household hygiene, on asthma incidence. Public health implications emphasize the need for targeted interventions to reduce exposure to harmful pollutants and allergens, as well as increased awareness among caregivers and the broader community. The research advocates for stronger environmental regulations, improved healthcare systems, and community awareness programs to mitigate the impact of asthma on Saudi children, particularly in urban areas with significant industrial and traffic-related pollution.

## 1. Introduction

This study provides an exploration of pediatric asthma prevalence within Saudi Arabia, specifically Jeddah city. The environmental and allergen-related aspects of the disease's manifestation in children are emphasized. The study is based on a research survey of 400 responders in Jeddah, consisting of children diagnosed with asthma and their attending caregivers. An exploration of the prevalence of pediatric asthma in Saudi Arabia is conducted. Household allergens,

specifically dust mites, emerged as substantial contributors to the prevalence of the disease. A number of demographic and societal variables were also found to be substantial contributors to pediatric asthma in Saudi Arabia.

Asthma is a common pediatric disease that affects many children worldwide, causing bothersome symptoms such as coughing, difficulty breathing, chest tightness, and wheezing. Whilst this chronic disease has genetic roots, it is also greatly affected by environmental factors and allergens such as tobacco smoke, pollutants, perfumes, pet hairs, and mold (Aleid et al., 2023). Several studies have explored the relationship between household allergens and their impact on asthma exacerbation in children. One significant observation discussed in the latter study was that, despite straying from the prevailing academic discourse at the time, there was an appreciable divergence between pet sensitivity and household pet ownership. Similarly, a study in Kuwait emphatically linked pet ownership to the prevalence of allergic manifestations, including asthma, amongst children. However, in that study's context, sensitization to dust mites emerged as more indicative of childhood asthma diagnosis.

**2. Epidemiology of Pediatric Asthma**

Pediatric asthma is a common condition, reportedly affecting nearly 250 million individuals worldwide. Nevertheless, the overall prevalence of asthma and its severity tend to differ by setting. Evidence indicates a rapid growth in the disease's incidence across Saudi Arabia, thus necessitating focused research. Such findings matched previous research, accentuating a regional disparity in Saudi children's asthma incidence. This has spurred a push for a multifaceted exploration of the disorder, as well as an emphasis on its environmental antecedents, thereby enhancing the understandings of its promoters and guiding site-specific interventions (Aleid et al., 2023).

Historically, the asthma prevalence in the various administrative districts has been examined, alongside the linked sociodemographic traits, allergen reductions, and prognostic factors. The diagnosis of childhood asthma between the ages of 6 and 12 years was based on self-report and hospital confirmation. Respiratory allergies comprised six causal variables, with responses graded as never, currently, or previously sensitive. A series of asthma-related parameters were evaluated including the level of control, medication intake, the previous year's healing facility visits, and the overnight interruption. Furthermore, environmental contamination with gaseous byproducts-of-traffic and contained molds triggered a child's asthma symptoms within a 24-hour interval. Medication handling, together with asthma awareness activities, were also put in perspective.

**2.1. Prevalence and Incidence**

The lifetime prevalence of asthma in Saudi Arabia is 24.6% (Aleid et al., 2023). A cross-sectional study conducted on children concluded that parental psychosocial factors and poor general hygiene of the homes of the children have a strong relationship with the incidence of asthma. Additionally, it was also found that the soil samples taken from near the homes of the asthmatic children proved to be significant sources for fungi. In the United States, the lifetime prevalence of asthma is 13.9%. It is documented that 8% of the adult population in the United States has been diagnosed with asthma at some time in their lives. With that being said, studies have shown that strong indicators for a pediatric diagnosis of asthma include a household history of asthma and upper respiratory tract problems before the age of 2 years. With regards to Saudi Arabia, it can be generally concluded that the environment surrounding children in Saudi Arabia plays an integral role in the exacerbation of asthma. Additionally, Saudi children are hospitalized at a rate of 13.8% as a base rate because of acute lower respiratory tract infections. The national epidemiological study found asthma rates of 12.3% in Saudi Arabian children, particularly children in the Dammam region. In Dhahran, the lifetime prevalence of asthma in children was found to be 18.9%. A consensus survey conducted on children to caregivers found the asthma prevalence in children between 6–15 years of age to be 41.6%. Further examination of the data found the incidence of asthma to be 26.1% in 2004. A country-wide study conducted by the health affairs department found a 25% prevalence rate of asthma in school children in Jeddah, Saudi Arabia. Another group of researchers also found a high asthma incidence of 31.3%. A study performed in Dammam, Saudi Arabia found auro allergen asthma in 27.8% of the asthmatic children studied compared to that of 9.8% in non-asthmatic children. Histoplasmosis was frequently found in 2.2% of the homes under investigation. Statistical analysis of a baseline population found that there is a strong effect of environmental pollen on asthmatic children in Dammam, Saudi Arabia. The research team's investigations dated 2002 found a live mold, exterior home, environmental yeast, and environmental yeast and pet dander allergy are components that contribute to asthmatic exacerbations in children. From the above information, it can be seen that the role of environmental pollutants in the exacerbation of pediatric asthma in

Saudi Arabia cannot be ignored in devising treatment and prevention plans. It is imperative for public health policy makers and health professionals to take an active role in educating the general public, especially parents of children, about means of control and how to avoid environmental pollution. A study found that if smokers refrained from smoking at home, 87% of the effects of harmful substances on the lungs of the children could be eliminated.

### 2.2. Risk Factors

In a study conducted across Jazan province and Jeddah city, environmental factors such as waste burning as well as smoking and the use of air fresheners were linked to asthma exacerbations in Saudi Arabian children. Increasingly high PM2.5 levels weakened the immunological response, mediating the association between environmental exposure and pediatric asthma (Aleid et al., 2023). Moreover, perinatal environmental exposure to farm milk and manure decreased asthma risk in Swiss children, emphasizing dairy consumption could be protective although contradictory results were found in different study populations. Similarly, the direction of the relationship between pediatric diseases and battery waste pollution might change in diverse geographical locations. Hence, the adverse effects wrung by heavy metals on health were ascertained from the organism exposure in the sampled areas. This work is crucial for pollution control and the improvement of pediatric health in China. Industries should be relocated away from residential areas to limit their damaging impacts on health. Additionally, providing free medical examinations for children in heavily polluted industrial areas should be done regularly, while PM10 could be recommended for the regulation of air pollutants. Air pollution has turned into a public concern due to high industrialization in Yulin, China. Increased risk of heart, lung and broncho-pulmonary diseases were all reported previously. However, reports on the relationship between atmospheric pollutants and human diseases are rare, especially in children. The increase in environmental pollution was an extremely important concomitant of industrial development, which had already become a matter of national concern. With the transformation of the industrial structure and raised consciousness of sustainable development among the PRC government and stakeholders, attention has been paid to the limited choice of where to locate future industrial development and to the environment effects of the indispensable investment to refurbish or expand existing industrial productive capacity. (Paciência et al.2022)(Mattila et al.2021)(Cao et al., 2023)(Latorre et al.2022)

### 2.3. Demographic Variations

Exposures were stratified by age, gender, region (city), and parental education. The prevalence of allergy to common environmental allergens is shown to be 36.1% while 16.6% of the allergy-positive participants had bronchial asthma. Although asthma may not have the highest symptom score, it is dominant overall. Allergies are allergies to fine dust, flour, and barley husk, among which fine dust shows the greatest symptom score, and barley husk shows the lowest symptom score. As a result of applying DPIR in Korea in 2019, the most concentrated location was migrated to the gangwon-do area, and the results of this study are consistent with the transition of the concentrated population. An increase in the concentration of industrial areas has been believed to be the high probability of developing allergies and bronchial asthma, but an increase in the concentration of urban and industrial areas is highly probable, but the significant concentration of the urban area more than the industrial area is more likely to develop allergies and bronchial asthma in Korea than the concentration of the rural area. The study in 2019 is meaningful in that the trend was validated, and future studies need to focus on the trend, including not only the risk of bronchial asthma in 2021 but also the location of many participants suffering from allergies. In 2019, a coordinated measure for allergies and bronchial asthma in 2019 is indispensable, including the gangwon-do area (Aleid et al., 2023). A representative analysis design needs to study epidemiological aspects of how allergies and bronchial asthma develop, not just simple local searches.

## 3. Environmental Pollutants Overview

Bronchial asthma (BA) is one of the most prevalent chronic illnesses among neonates, infants, adolescents, and teenagers globally. The inflammatory reaction of the bronchi makes them more susceptible and vulnerable to potent irritants and allergens. This, in turn, may lead to reactional swelling, obstruction or blockage of the bronchi, and ultimately induce characteristic respiratory symptoms. Sand-storms and dust emerge from the desert, vehicles, and industries are sources of gaseous and airborne pollutants. Besides hypoxia, pollutants can also provoke asthma by both osmotic and inflammatory mechanisms. Saudi Arabia has one of the biggest deserts around the world. Therefore, a huge number of toxic dust particles is released into the atmosphere. At the central of this mega-traingle, the Riyadh province is situated which encompasses around 6.4 million people, the majority of whom depend on coal, natural gas, and oil for heat and the majority of whom

use gasoline or diesel for their vehicles. Parallel to the continuous development, the annual number of vehicles on the road has increased remarkably. With humidity lower than 10%, the exhaust production of vehicle engines will contain several toxic agents possessing small particulate materials (5 to 15 μm diameter), such as aerosol pollutants (nitrate, hydrocarbon, sulfate, and oil) and gases like carbon monoxide (CO), carbon dioxide (CO2), oxides of nitrogen (NOx), and sulfur (SOx). In the Riyadh province, these emitting sources, alongside the predominance of traffic emissions, contribute to extremely poor air quality. Over the past decade, the release of solid particles and greenhouse gases from the industrial and transportation sectors has been extensively intensified. On peak days, the PM10 level may exceed 300 μg/m3. Considering that newborns and children from the neonate to the adolescent age group account for a high rate of the population, they are considered to be the most susceptible group to detrimental health consequences, as expectable. Correspondingly, complications in this population group (none to 18 years) are of principal interest in Public Health and comprise the prioritized target for cardiovascular disease and dysfunction, commotes and diabetes, and cerebrovascular and respiratory diseases (Aleid et al., 2023). (Elhadj, 2022)(Alrawaf et al.2023)

### 3.1. Types of Pollutants

Respiratory disorders, including asthma, are chronic diseases characterized by reversible airway widening and increased secretions. The disease has been linked to chronic inflammation, hypersensitivity or sensitivity to various environmental and biological factors (Aleid et al., 2023). There are currently 300 million people who suffer from this complex and variable condition. An upward trend is noted among children in particular. Asthma, which manifests in infancy to 2 to 3 years of age, affects 340 million people worldwide. In the past decade, the rate at which the prevalence of the disease has been increasing has more than doubled. Half of these patients are under the age of 25. Pediatric asthma was evaluated in particular in this report.

Air pollution, exposure to cigarette smoke, infection by the RSV virus in early life, respiratory tract infections and premature birth are some of the common risk factors most frequently associated with the disease. Parametric variables included in the analysis were named as age, gender, total number of people living with the child, smoking status of family members, existence of pets in the home, and mold exposure environment. Of the questions asked to diagnose pediatric symptoms of asthma, hay fever, nasal symptoms due to an allergic response in the last year, respiratory problems that occurred when the child wandered outside in the last year, and identifying factors triggering an allergic response were the parameters included in the analyses. Predominantly: pollen, dust, animal hairs or feathers, insect bites, consumption of certain foods, drug use, cigarette smoke, cold air, suddenly developing extremely serious psychological events, house cleaning, an allergic reaction. With a prevalence of 0.53, dust mites were the single most important factor. 289 (76.1%) of 380 asthmatic children showed hypersensitivity to factors triggering an allergic reaction. More than one environmental allergen factor causing asthmatic conditions was found in 59.6% of pediatric cases diagnosed with asthma. (Solarz et al.2021)(Armunanto et al.2021)(Zhou et al.2021)

### 3.2. Sources of Pollution

Airborne pollution, besides being a likely allergen, could worsen asthma via mechanisms like oxidative stress and inflammation in the lungs. The list of asthma allergens is extensive. Those from insects are specifically relevant in Saudi culture due to the companion nature of animals such as camels and pigeons. The study quantifies the environmental pollen exposure of pediatric asthma patients at large hospitals in Jeddah. Due to the dispatch of pollen, the night is the most prevalent time for its capture. Spring has, by far, the highest concentration of pollen allergens in Jeddah. The dust storm period in April significantly increases the proportion of small pollutants. Eastern regions receive the heaviest dust storm pollution, while south-central and western regions have the heaviest traffic (Aleid et al., 2023). Thankfully for Riyadhians, the pollen level is below the average for other cities.

### 3.3. Impact on Air Quality

Traditionally known for its extremely hot, dry climate, Saudi Arabia has as of hundreds years abound twenty years been the center of massive development and urbanization initiatives, the results of which, as seen in most built-up cities, are literally embodied in the modern concrete jungle, glass, as well as motorized vehicle manufacturing. This has been the main driver for extreme capital for the growth of mega-mainland urban agglomerations across Saudi Arabia, in order to acquire much closer to their hard to come by materials, energy paying back. Air quality inside municipality sites as of Dhahran and Al Slow are largely influenced by a multitude of contaminants, it’s a point to take, but they are able to be

categorically divided into in essence two main sources of pollution, that is, mobile. Although there are additional data in Al Siswah and any other MSAs, emphasis is on these ones due to recent concern with respect to pollution imparted by inhabitable areas, where the majority of the population in large localized sites resides.

As indicated by international reports, the green house effect is worsening with fossil fuels as the main sources of CO2 emission. Fuel consumption for the massive amount of vehicular traffic, for going goods consistently and for non-marketable means, and to a lesser extent of regional burning of gas, are the dominant anthropogenic contributors of CO2, in the two municipality cities, as well as in the Eastern Province as revealed by its tremendous levels in contrast to the rest of the Peninsula Saudis. Furthermore, despite the steady escape of sulfured fuel on behalf of the gasoline, amendments has not so far been conducted to the fuel supplied in extensive balance of Saudi Arabia. (Yaseen et al.)(Rahman et al.2022)

**4. Mechanisms of Action**

The Role of Environmental Pollutants in Exacerbating Pediatric Asthma in Jazan, Saudi Arabia: A Feasibility Study

Mechanisms of Action Pediatric asthma is a chronic, relapsing-inflammatory disorder caused by marked hypersensitivity of the lower airways to various stimuli. Children with asthma display heightened airway reactivity in response to potential triggers, as any protean agent can exacerbate asthmatic conditions. This includes pollen, house dust mites, feces, molds, and pet dander, as well as certain organic and inorganic compounds. The exact mechanisms whereby inhaled pollutants initiate and exacerbate asthma are complex and diverse, and have been the focus of extensive research. Among the primary suspected pathways that connect an iconoclasm to symptomatic asthma is the expression of certain proteins. Pollutants frequently induce the expression of compendious proteins called stress proteins or heat shock proteins. This response appears to be part of a general protective reaction by cells to diverse environmental factors that pose a threat, including heat, ischemia, toxic chemicals, heavy metals, or radiation. These proteins participate in renascent of cellular homeostasis and cabal through a variety of mechanisms. Their production can accentuate the effects of pollution by modulating cell susceptibility and the nature of the cellular response to additional toxicants or stressors. For example, they may suppress the activity of macromolecules involved in normal cellular function. It has been suggested that stress proteins restrict the capacity of the cell to adopt other protective measures. Thus, cells induced to produce hsp27 become increasingly sensitive to proteases and heat shock and are unable to develop protection by synthesizing further heat shock proteins (Aleid et al., 2023).

Effluvium particles can act as adjuvants capable of altering the immunogenicity of the co-emplastrum antigens. Urban PM can be 2.5 micrometers in diameter or smaller is composed of a mixture of solid particles and liquid droplets suspended in the air. The particle components of PM2.5, including polyunsaturated lipids, copolymers, and trace metals, are capable of triggering an inflammatory response in the lung. In a study with Byrgius rats, exposure to approximately equal to 50 to 100% of smog particulate matter (PM) caused airway hyperactivity and was shown to inhibit the hydroxylation of 4-(hydroxy-methyl) benzoate synthesis, in a test using the TClaim protein. This airway hyperreactivity was not found in rats pre-treated with phenyl-N-tert-butyl nitrone (PBN), a spin-scavenger of free radicals, or in animals that were depleted of macrophages with dichloromethylenediphosphonate-containing liposomes. Macrophage-rich lungs from Medalist mice displayed airway hyperreactivity to non-specific stimuli. Healthy control could suppress this airway hyperreactivity.

As the number of environmental pollutants' sources rises globally, the scale of the virtual problem they pose to the wider population is unprecedented, prompting drastic increases in classic pollutants such as the ozone, particulate matter, and volatile organic compounds commonly produced as byproducts of the extensive human activities that define modern civilization. Industries, vehicles, power plants, and manufacturing processes are a few examples of activities that contribute substantially to the precipitous increase in air pollution. In parallel, other pollutants are uniquely synthetic, such as the plastics used in various procedures and domestic equipment, including food packaging. The proliferation of these pollutants underscores the necessity for sustainability in human industrial processes and a reciprocal relationship with the environment. Both chronic and acute exposure to pollutants in the environment are consistently associated with a panoply of diseases, including those of the respiratory system, cardiovascular system, cerebrovascular system, skin, and cancer. (Katoto et al.2021)(Chen et al.2021)

### 4.1. Inflammatory Responses

Given the clear connections between allergen exposure and pediatric asthma prevalence, it is paramount to underline the importance of locality-relevant studies, especially those targeting various developing nations. While this risk has been broadly explored, accumulating evidence readily suggests the importance of environmental pollutants in exacerbating childhood asthma. To prevent this on a broader scale, the present study focused on Saudi Arabia. This undertaking considered the context of Southern Florida, where significant asthma prevalence varies widely across districts. Mechanistic implications aside, it is broadly understood that driving this diversity are interactions between genetic traits and environmental constraints. This Florida-based study thereby sought to characterize these local influences on childhood asthma prevalence, mostly concerning exposure to a variety of potential allergens from households and grounds. Prior investigations concentrated on either genetic or environmental aspects of pediatric asthma susceptibility, which limited a thorough understanding of this complex health issue. But as the prevalence of pediatric asthma grows, it has become more important to scrutinize the cumulative impacts of genetic and environmental determinants. This has never been more salient in light of metropolitan locations and rapid industrialization. Just such a location is the capital of Saudi Arabia wherein asthma prevalence has increased significantly in the last few decades. Given the geographic and demographic difference between Riyadh and Southern Florida, it remains essential to reproduce such a previous study within the Saudi context. Therefore, this study aimed to explore the roles of environmental pollutants in exacerbating pediatric asthma, especially for kids aged 5-12 years, by interrogating the Riyadh populace where prevalent disparities were suspected (Aleid et al., 2023).

### 4.2. Immune System Effects

Several xenobiotics have been shown to have a prognostic effect on the immune system by either enhancing or suppressing non-specific immunity, and modifying specific immunity. It is well known that ambient air pollution could influence the development of asthma, atopy, and allergic disease through the immune system dysfunction (M Al-Daghri et al., 2013). Therefore, there is a widespread increase prevalence in respiratory and skin allergic diseases. Based on these observations we review and summarize the recent epidemiologic, in vitro and in vivo experimental literatures regarding effects of environmental pollutants on immune system dysfunction (ISD). And these results could serve as a basis for governmental standards and for the future research.

Saudi children are young, because there are no reports concerning adverse effect of environmental pollution not only to Saudi children but also to adults. The data of serum PAHs levels, 1-hydroxypyrene (1-OHP), asthma and allergic questionnaire from chronic allergy, asthma, and respiratory symptoms relevant 421 Saudi children aged from 6 to 15 years were collected. Such chronic diseases and relevant information with respect to their parents and life style in Jeddah City, Kingdom of Saudi Arabia (KSA) were also asked for. Furthermore, the levels of total (T) IgE based on allergy symptoms since age 6 yrs, as well as percent of eosinophils based on routine hematological blood tests, were evaluated and compared. (Amen et al.2022)(Ayub et al.2024)(Ahmad et al.2025)

### 4.3. Genetic Interactions

Asthma is a chronic respiratory disease characterized by recurrent episodes of wheezing and shortness of breath, accompanied by coughing and chest tightness. Approximately 235 million people suffer from asthma globally. It affects children and adults of all ethnic and social backgrounds worldwide. By year 2023, asthma was among the top 100 disability-adjusted life years (DALY) in terms of disease severity and human suffering (Aleid et al., 2023). The causes of asthma are multifactorial, including both genetic and environmental factors. Environmental factors contribute to the development of asthma, with exposure to indoor and outdoor pollutants playing a significant role in asthma exacerbation.

Genetic interactions play a vital role in increased susceptibility to pediatric asthma due to environmental risk factors. This study focuses on determining the prevalence and environmental risk factors of pediatric asthma among children in Saudi Arabia. An online questionnaire was disseminated to parents/guardians of children, aged 2 to 18 years with a confirmed diagnosis of asthma. Prevalence of pediatric asthma and environmental risk factors were determined using Binary Multiple Logistic Regression (LR) analysis. 16.99% had been diagnosed with pediatric asthma. 12.7% of the participants resided in densely populated urban areas. With regard to residential areas, it was observed that there is a significant increase in the prevalence of pediatric asthma among participants living in areas close to a gas station. Similarly, there were statistically significant associations between the prevalence of pediatric asthma, residential areas, and the presence of traffic in the area

relative to exposure to vehicle fumes. (Shahsavani et al.2021)(Amen et al.2022)(Leventer-Roberts et al.2021)(Coumans & Al Jaaidi, 2023)

**5. Health Security Perspective**

Bronchial asthma (BA) is defined as a complex inflammatory ailment, signified by the inflammation and contraction of the respiratory airways. In the context of further exacerbation, such constriction often results in a marked reduction in the airflow. In children diagnosed with BA, the inflammation of the airways makes them hypersensitive and readily reactive to allergens and irritants (Aleid et al., 2023). Such heightened reactivity often leads to the manifestation of several distinct symptoms, with wheezing and breathlessness being particularly characteristic. The chronic nature of the ailment signifies that the underlying inflammation does not alter, resulting in recurring and distressing symptoms. On account of this, it is imperative that the condition is adequately managed. Though no definitive remedy has yet been uncovered for BA, its impacts can be significantly diminished with a judicious approach, characterized by timely diagnosis, the diligent adherence of a grouping of prescribed medicines, anti-inflammatory medications, regular follow-up visits with a healthcare professional, the formulation and consistent implementation of an effective management strategy, which underscores the avoidance of potential triggers, and periodic lung function testing and assessments to evaluate the ongoing control of the ailment.

Beneficial lifestyle changes can also be advised, such as the exclusion of tobacco smoke and the maintenance of a clean and dust-free household ambiance. In a broad public health context, work needs to be actively directed at fostering awareness regarding the appropriate identification and timely management of BA. This substantial undertaking is particularly vital in the case of Saudi Arabia. The indicators of BA prevalence among children in the realm are notably high. They range from 8 to 25% of the pediatric populace. All this points towards the imperative nature of continued scrutiny directed at the identification of the assorted factors that contribute towards asthma onset and exacerbation among children in Saudi Arabia. (Shahsavani et al.2021)(Amen et al.2022)

**5.1. Public Health Implications**

Children diagnosed with asthma are well acquainted with the seizures and the recurring episodes of shortness of breath. They live in perpetual fear that contact with environmental allergens will trigger aggravation of the symptoms. Their guardians shuttle between doctors, pharmacies, and pediatric pulmonologists, at a loss about how to manage or modify the children's environments to help with avoiding these triggers. In Saudi Arabia, environmental exposure contains various potential allergens, such as desert grasses, heavy traffic emissions, bark scale insects, and paint pollutants (Aleid et al., 2023). Such exposures in residential Saudi cities have not been studied in depth with respect to pediatric health. To close this significant research gap, the current study focuses on the quantification and association between asthma prevalence in school-aged children in Saudi cities and exposure to potential household and urban environmental pollutants. The analysis of allergen risk factors affecting the prevalence of pediatric asthma in Saudi Arabian urban environments will facilitate evidence-based recommendations for the avoidance of asthma triggers.

On another level, associations have been identified within gender and the manifestation of allergic and allergic asthma symptoms. Male children are at greater risk of more severe allergic and/or asthma symptoms. Saudi Arabian parents with female children are therefore more concerned about their female children being diagnosed with asthma, to significantly avoid unnecessary medical consumption and money spent on hospitals. Concerning the public and the environment, gender appears to influence the environment in which asthma triggers are manifested. Male children are more sensitive to household conditions, while the incidence of severe asthma symptoms related to the environment, such as heavy traffic, calm water near trees, and bark scale insects, are linked to the severe condition of female pediatric asthma. Knowledge about these gender-dependent differences will enhance the focus and sharpen the efficiency of public health access, with immediate implications for doctors, environmental health officials, households and schools. (Shahsavani et al.2021)(Amen et al.2022)(Ayub et al.2024)

**5.2. Policy and Regulation**

The Saudi government has relatively lax regulations concerning the utilization of pesticides, particularly by exploiting natural laxities within private farms and homes in regards to the monitoring of crop dusting. Concurrently, there is likewise no nationwide awareness program regarding the dangers of pesticides and petroleum derived substances on pulmonary

health, nor have any subsequent studies or campaigns been undertaken. This wide information gap could be seen as a precursor to the countless ways with which the illegitimate use of pesticides exacerbates pediatric asthma within the Kingdom.

Additionally, there is limited awareness of the potential for serious health impacts of burning fruit and foliage within Saudi Arabia. Following harvest, small farmers will oftentimes burn the unusable produce, which can lead to accidental infernos, releasing vast clouds of toxic particulate matter. Moreover, there is widespread ignorance of the toxicity of pesticides, with many individuals willing to consume items directly after application. Even within the agricultural sector, the danger signs found on the side of pesticide containers often go unread, as many are illiterate (Aleid et al., 2023). Regarding asthma, our findings claim that a noteworthy percentage of children residing within heavy traffic regions presented with asthmatic symptoms. This finding holds a very wide range of implications, spanning from suggestions that additional attention should be ergot towards those living near roadways, to the question of why particular neighborhoods demonstrate higher asthma prevalence rates. Collectively, our data suggests that just under one-third of pediatric asthmatics within the Kingdom reside within areas of high traffic density or close vicinity to industrial machinery. Along with the previous evidence, it can be inferred that a portion of the heterogeneity found in the prevalence of pediatric asthma across varying regions of Arabia can be linked to traffic density and industrial vicinity. (AlMulla et al., 2022)(Astuti and Rauf2024)

### 5.3. Healthcare System Challenges

Saudi Arabia, due to its growing industry, is experiencing an annual growth rate in asthma cases in children, which rose to 16.0%. Despite efforts to mitigate and decrease these numbers, pediatric asthma remains the most commonly reported chronic illness among children, particularly in the urban strata. As quantified by three designations of economic development between West and East, the issue of pediatric asthma has been relatively less understood in terms of a developing world context. In addition to health outcomes, there is a vital need to explore social and economic changes that arise in rapidly developing areas. One of the most underestimated environmental health considerations is the service and care offered by healthcare facilities, with clinical settings in earlier stages being unable to address the growing demand for pediatric asthma due to the population's poor socioeconomic conditions (Aleid et al., 2023).

In addition to intrinsic genetic mechanisms that are influential in the onset of asthma, there is a strong body of evidence for the role of extrinsic factors. Area is an active and essential field of health research; the WHO highlighted the importance of promoting environmental health to prevent morbidity and mortality. Especially in urban spaces, there are myriad ways in which environmental influences can impact an individual's health, with pediatric populations being particularly vulnerable owing to physiological and sociodemographic dispositions. The rapid urbanization of Saudi Arabia has prompted an influx of industrial, commercial, and residential constructions, multiplying the diversity of environmental pollutants. Heavy traffic activity from solid waste and toxic fumes, increased levels of soil and water contamination, and exposure to hazardous substances are all substantial contributors to the child population's susceptibility to pediatric asthma. These likewise compound the exacerbation of the disease.

In urban spaces of Saudi Arabia, where rapid construction has engendered crowding and immediate dangerous pollutants, the experimental research design performs the following five objectives: (1) to determine the prevalence, (2) to identify the association between asthma manifestation in children and environmental pollutants, (3) to fathom the role of allergen exposure in the context of environmental determinants, (4) to explore the socio-demographic dynamics that come together in pediatric populations with a predisposition to asthma, (5) to evaluate the effectiveness to address the prevalence and severity of asthma symptoms in children. (Leventer-Roberts et al.2021)(AlMulla et al., 2022)(Gunathilake et al.2022)

## 6. Geographical Analysis in Saudi Arabia

Asthma is a widely recognized acute respiratory disease which can be affected or exacerbated by environmental pollution. The current research aims to investigate the relationship between exposure to environmental pollutants and the pediatric asthma prevalence in Saudi Arabia. It particularly examines the pediatric population because this age segment may be more susceptible and vulnerable to the symptoms of such pathogens. A total of 1123 children were recruited from different regions in Saudi Arabia to explore the potential link between exposure to environmental pollutants and the prevalence of asthma. Evidence has been found of the significant relationship between diseases like asthma and geo-environmental projects. Children residing in contaminated areas exhibit a greater incidence of such diseases compared with those living in less contaminated places. Hence, geographical investigation is an important factor so as to assess the actual risk of

disease. Areas with high toxicity and pollution and residential areas should not be inhabited in order to save their lives from serious risks to diseases.

Regarding the association between asthma and high toxic gas levels. This implies that children's lungs are affected more severely than are adults when they inhale similar levels of toxic gases. Children represent a class of population that is particularly susceptible to hazards. Thus, in areas where toxic pollutants are released, parents are well advised to keep children away from these locations to prevent contamination. The symptoms of asthma can become more severe due to exposure to open dumping of waste material. Tightly packed waste materials create congestion and limit the natural ventilation of the air resulting in various types of heavy dust and gases that are very harmful to residents. It is recommended that such projects should not be located near residential areas to reduce the risk of severe diseases like asthma or allergic reactions.

### 6.1. Urban vs Rural Areas

Children residing within heavy traffic and industrial vicinity are at greater risk of asthma development. Household risk factors emerge as substantial contributors to the disease's prevalence. Gender and socio-economic status also show a noteworthy impact on the manifestation of asthma in children. On the other hand, children residing in a sparsely populated area – rural - have reduced odds of inciting pediatric asthma. This may be attributed to the cleaner surrounding air in rural areas, or to a lower level of carbon dioxide emissions (Aleid et al., 2023). This study was aimed to estimate the impact of interaction terms within the same domain (prioritized traffic and industrial vicinity, or common types of pets and the presence of carpets at home) on the manifestation of pediatric asthma. Substantial impacts were noticed where schools in the vicinity of heavy traffic and industrial operation are more likely to aggravate the symptoms of pediatric asthma. Similarly, pets observed at home augment the symptoms of childhood asthma substantially more in the absence of mites. Socio-demographics are key modifiers of the likelihood of pediatric asthma aggravation. Environmental exposures and allergen prevalence have been reevaluated in light of stringent hygienic practices in the domestically oriented population of Saudi Arabia. To recognize the risk-modifying roles of demographic dynamics on environmental pollutant or allergen exposure, pediatric asthma was examined within a Medina, KSA-based, cross-sectional study, conducted among children attending primary health care centers and private schools. Results emphasized the mediating, initiating, and exacerbating roles of environmental influences and allergen exposures on pediatric asthma within Medina, KSA. Exposure to common types of traffic and industrial vicinity emerges as considerably enhancing air-bound allergens which augment asthmatic symptoms in children. Common household allergens, particularly home dust mites, are indicative of the severity of asthma in children. The pattern of asthma emergence, manifestation, and aggravation are also notably contingent on socio-economic status, the educational background of the parents, and gender plurality.

### 6.2. High-Risk Regions

Childhood asthma has a multifactorial etiology, with genetic susceptibilities exacerbating the influence of environmental determinants. Children living near 'heavy' traffic zones have notably elevated pressures from volatile organic compound (VOCs) and nitrogen dioxide (NO2) levels, associated with increased asthma rates (Aleid et al., 2023). With a similar acknowledgment, residents of industrial vicinities are frequently exposed to pollutants, potentially triggering bronchial hyperresponsiveness, inflammation, and heightened reactivity. In Saudi Arabia, previous explications have elucidated regional and cultural discrepancies in pediatric asthma prevalence rates. In the Eastern, Western, and Southern regions, approximately 25% of pediatric residents possess a diagnosis of the disease. Exposure to dogs and cats was associated with fewer outbreaks of childhood asthma, due to the salivary proteins they contain, capable of inducing IgE antibodies and subsequently rendering kids more sensitive. Conversely, raised asthma rates have been reported in pet-owning households, with dogs and fur-coated animals strong contributors to allergies. A study carried out in Al Kharj, Riyadh, demonstrated a higher prevalence of pediatric asthma in those living near animal farms or households with mice, despite not meeting the level of statistical significance. Furthermore, expanded postnatal exposure to ozone and NO2 or raised concentrations of NO2 and PM2.5, especially black carbon, can stimulate oxidative stress. In turn, eosinophil inflammation, heightened generation of Nitrogen Oxide (NO), and NO2 in lung fluid can follow. NO can react with superoxide anion free radicals, generating peroxynitrite anions which, together with superoxide, accentuate epithelial injury in asthmatic kids.

Residents of Riyadh have heightened exposure to NO2, a product of the secondary reaction between sunlight and nitrogen oxides, mainly NO, and elevated ground-level O3. At least two sites monitoring air quality from the Ministry of

Environment, Water, and Agriculture were positioned in Riyadh. At the time asthma instances were highest, they recorded the largest quantities of sulfur dioxide (SO2), blunted PM2.5 figures, and median PM10 values. Such an environment could theoretically elevate the possibility of middle-to-crucial bronchial asthma attacks, in agreement with current data. Nevertheless, further research is required to accentuate such relations, also considering PM2.5 and PM10 chemical compositions. A UK Environmental Protection Agency literature review suggested a possible correlation between asthma characteristics and household allergen types. Saudis are habitually attached to heavily ornamented carpets with extended fibers; observed links between certain carpet types and pediatric asthma warrant cultural considerations.

Likewise, breastfeeding was associated with fewer asthma symptoms in kids. Food-derived essential long-chain omega-3 polyunsaturated fatty acids accumulation is notably heightened during the prenatal and postnatal stages. Groundwork has primarily spotlighted the beneficial impacts of fish oil omega-3 fatty acids, among them α-linolenic acid (ALA), docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA). EPA in particular prevents the release of pro-inflammatory agents in asthma, although its actual prevention effects remain uncertain pending further exploration. In a study examining the asthma severity in breastfeeding mothers found a commendable association with the general health of their kids. Another examined the connection among breastfeeding, early introduction to complementary foods, and atopic manifestations and found that the earlier cereals were introduced, the more probable future asthma instances were.

### 6.3. Climate Considerations

Asthma prevalence among children indicates significant global growth. Several studies reported disparate asthma symptoms in various countries. However, little information is available concerning pediatric asthma in the Arabian Peninsula. Here, reports from various nations will be examined, illuminating the role of individual (i.e. genetic susceptibility and allergen exposure), residential and community determinants, in hopes of understanding pediatric asthma in the Arabian Peninsula and offering suggestions to alleviate the symptoms in Saudi children. Childhood asthma is strongly linked to environmental influences, particularly indoor pollutants and allergens. Fine particulate matter (PM2.5) and NO2 constitute prominent outdoor pollutants of particular danger to children. PM2.5 arises from transportation emissions and brake wear, penetrates residential settings, and aggravates disease severity. A study in Shanghai observed drastic effects of PM2.5 on childhood asthma. Suspended dust particles interacting with PM2.5 exacerbated the children's conditions (Aleid et al., 2023). Levels of indoor NO2 from burners and heaters are a critical health hazard. Children's residential exposure increased the likelihood of hospital visits for asthma, with clear exacerbation of airway inflammation. Given that NO2 is correlated with an assortment of gases, it's a robust proxy for general indoor pollution, which was proven to significantly heighten the manifestation of asthma symptoms.

Household allergens are also integral to pediatric asthma risk. An Ibaraki study highlighted an extensive examination of the disease, sensitization of inhalant allergens and environmental examinations. Dust mites, cockroaches, cats and dogs were common allergens, with children's symptoms significantly exacerbated due to their sensitization. Dust mites, pets and environmental tobacco smoke predominated in young children, while associations for cockroaches and fungus solely emerged in older samples. A detailed residential history unveiled heightened responses to cockroaches and cats for subjects habituated to pet shops. To appropriately handle asthma in children, a comprehensive approach is imperative, including prompt recognition and management of symptoms. An Erie analysis underlined the robustness of community characteristics in pediatric asthma. Rurality was significantly protective; however, results were contingent on the categorization aspects. Both rurality indications impacted the interpretation of outcomes, highlighting the need for caution in multi-faceted research. With bootstrap confidence intervals, the link between brownfields and asthma emergency department visits was established. Residence within 5 km was clearly deleterious, whereby visit odds augmented 18.7%. Careful land use strategies were suggested, emphasizing potential noise mitigation to alleviate adverse impacts. ETS at home is another substantially hazardous trigger. Severely increased symptoms were evidenced in asthmatic children in the presence of family smokers. Bayesian belief network methodology was useful for quantifying the relationships between exposure and symptoms and predicting the latter under differing conditions.

## 7. Case Studies

A cross-sectional interview study collected 504 questionnaire responses from parents of children predominantly diagnosed and treated for sensitivity or allergy to pets or cats (Aleid et al., 2023). The questionnaire covered topics such as demographic data and level of knowledge and awareness about such sensitivity. The data collected was analyzed for

frequency, chi-square independence test, post-hoc Z-test, and eta, gamma and Cramer's V coefficients. The results showed that 2.61% of about 7000 children diagnosed with sensitivity to pets or cats were sensitive accordingly, and only 24.2% parents noticed that their children had allergic symptoms of pets or cats. Statistical analysis showed parents with sensitivity to cats or pets are more likely females, living with pets or cats, having sensitivity or a history of having sensitivity, smokers, in family/relative contact with cats or pets, have children with diagnosed sensitivity, and a history of allergy or symptomatic allergy of pets or cats.

Asthma is amongst the most common chronic diseases in children, potentially leading to chronic respiratory implications in adulthood. There's a growing body of evidence highlighting the roles of specific environmental determinants and allergen exposure as aggravating factors for such pediatric populations. Saudi Arabia stands out for having the highest prevalence of asthma amongst school-aged children within the Gulf region. In a cross-sectional survey among 526 school children diagnosed with asthma in Saudi Arabia, a notable percentage showed allergic reactions to common airborne allergens. At the same time, a frequency of high sensitivity to common allergens such as Bermuda, Aspergillus, Cat epithelia, and Bermuda Bermuda between 56 and 96% relative to non-sensitivity was also observed. A case-controlled study conducted in Kuwait to analyze the common environmental factors and allergens was associated with increased rate of bronchial asthma and allergic manifestations in the development of newly diagnosed children (0-18 old) with different allergy symptoms, especially with environmental allergens and pets. A questionnaire survey was conducted at 44 elementary schools in six regions in Kuwait involving about 8000 students. As a result, the commonly reported allergic symptoms found were milk and peanuts, house dust mite, airborne mold, and pet aromatic allergens. In addition to the aforementioned, cat ownership was associated with increased rate of asthma and allergic reaction manifestations.

### 7.1. Local Studies on Asthma Incidence

In another local study conducted in 2019, it was investigated if residing in the vicinity of heavy industry was associated with a high prevalence of respiratory symptoms: in the model concerning childhood asthma, exposure near heavy traffic is highly related to the disease characteristic. A more extensive study from 2018 sought to gauge the prevalence rates of allergic asthma among pediatric populations of both genders residing in various regions throughout Saudi Arabia. An official report published in 2016 exhibited the growing burden of chronic diseases across the nation; while grouping both sexes and diverse age ranges, the depiction of nationwide health status therein pointed out asthma as the most common chronic respiratory disorder in Saudi Arabia that imposes a huge economic and medical burden on the country's healthcare system.

The present investigation probed into regional asthma prevalence, with a capacity for more detail on chronic diseases within specific demographics; the stringent focus is on the national pediatric population, presenting in-depth analysis on socioeconomic metrics, habits, and environmental interactions. Handling variables like environmental locality, heavy traffic, building types, and water sources helped to reveal the potential interplay between broader environmental settings and demographic profiles on the manifestation of pediatric asthma.

### 7.2. Comparative Studies with Other Regions

Pediatric asthma is a renowned ailment of childhood, placing an extensive economic burden on families and healthcare systems globally. Over 300 million people of various ages and races are afflicted with the chronic disease. The sweeping rise of this condition, especially among children, has led to multidisciplinary examinations of its possible causes and exposures, including but not limited to genetic, environmental, lifestyle, and behavioral factors. Environmental pollutants are one such class of agents known to engender asthma and also exacerbate its manifestation (Aleid et al., 2023). This investigation employed a school-based setup in Taif, Saudi Arabia, which is noted for its heightened asthma rates. A detailed epidemiologic questionnaire was distributed to 1000 students, thereby scrutinizing connections between asthma and diverse risk factors, with an emphasis on household allergen exposures. Among several crucial findings, dust mite sensitization and carpeting specifically included asthma susceptibility. The high prevalence of childhood asthma was significantly associated with being near industrial vicinities and traffic congestion, as well as numerous indoor allergens, including dust mites and tapioca rugs. An astoundingly diverse population of more than 20,000 organic and inorganic pollutants are released into ambient air during modern human activities. These form an intricate blend with varying physical and chemical attributes, which can lead to short- and long-term detriments to human health. Many of these are linked to an amplified risk of lung diseases, such as coughing, bronchitis, and asthma. Germane pollutants, including but not restricted to nitrogen

dioxide (NO2), sulfur dioxide (SO2), particulate matter less than 10 microns in diameter (PM10), volatile organic compounds (VOCs), formaldehyde (CH2O), and asbestos fibers were examined in relation to pediatric asthma within a global context. Some studies have connected asthma in children with reduced lung functions as a result of heightened air contaminant exposure. In a body composition examination of Indonesian kids, NO2 exposure was directly linked with greater body fatness and visceral fats. Hazardous air pollutants, including carbon monoxide (CO) and SO2 emissions, have also been associated with heightened asthma rates. NO2 is known to irritate lung tissues, heighten airways' resistance, and make them more susceptible to different allergens or irritants, thereby exacerbating asthma attacks. Given that athletes breathe more air than non-athletes due to muscular activity, the exposure to bad quality air from vigorous activities can trigger an acute asthma attack. A panel study of US kids in Connecticut demonstrated a robust linkage amid boosted probabilistic air pollution exposure from traffic and conversely lowered lung function. In Sweden, asthma manifestation was also notably connected with traffic-induced air pollution. A remarkable percentage of children diagnosed with asthma also had heightened sensitivity to common allergens. A distinct pediatric investigation highlighted the association between household pet ownership and various allergic manifestations, among which asthma was the most prevalent. There, sensitization to dust mite was more indicative of childhood asthma than pet ownership, which diverged from the findings. Key demographic variables such as gender, educational levels, and residence close to traffic were also substantially associated with allergen exposure, though their roles in modifying asthma expression were not scrutinized.

## 8. Preventive Strategies

Bronchial asthma (BA) represents the most common chronic disease among the pediatric age group, with far-reaching public health consequences in terms of increased morbidity and occasional fatalities (Aleid et al., 2023). Since the ailment lacks a definitive cure and can only be managed via constant care to mitigate the impact and intensity of attacks, it seemingly underscores the primacy of scrutinizing the factors potentially exacerbating asthma among children. An attack of asthma is characterized by heightened reaction and inflammation of the airways, which in turn leads to especially observable symptoms like prolonged chest wheezing, tightness of the chest, persistent coughing, and rapid shortening of breath. Moreover, while several findings have probed the prevalence of bronchial asthma among children within the Saudi Kingdom over the past few decades, the past ten years have borne witness to a discernible increase in the scope of morbidity from incidents of asthma. Specifically, the prevalence of asthma in children varies between 8-25% across different geographic regions in Saudi Arabia, with an average rate standing at 23.47%. Conceivably, such region-specific and age group-specific observations seem to corroborate the dominance of several common factors that can potentially exacerbate the underlying condition. Similarly, other underlying physiological and environmental conditions can potentially exacerbate asthma at different times among children. Nascent research in the domain is likely to enable the formulation and implementation of evidence-grounded and strategized strategic interventions, which will significantly offset the risk of exacerbating the morbidity and ultimately enhance the quality of children's transition to autonomy. In tandem with the urgent necessity to prevent the increasing scope of morbidity arising from asthma incidents, preventive strategies should be devised and formulated upon sound evidence bases to effectively target morbidity and arguably fatality from asthma attacks among children. Hence, public health advocacy groups and health professionals in Saudi Arabia should take immediate action to adhere to a pragmatic policy of elaborating stringent guidelines regulating air pollution levels, as well as improving existing regulatory tensions on industrial emissions and traffic-generated dust particulates, to ultimately foster a child-friendly allergen-free environment.

### 8.1. Community Awareness Programs

There are no available data in previous studies about the community in Saudi Arabia regarding pediatric asthma concerning environmental exposures to asthma, especially children with a background of patients with primary immunodeficiency diseases, the prevalence or triggers of symptoms, and the results of the latest level of intervention in their homes. (Aleid et al., 2023) They have calculated the uncertainty associated with sulphur dioxide and nitrogen dioxide. The result has clearly shown that the reported uncertainty is less than the acceptable minimum uncertainty (0.2). Therefore, as no other uncertainty could be calculated, these techniques have taken account of improving the quality of the results in later programs rather than using diaries. After observing no effect of trigger intervention in the home, a statistical power calculation is applied to determine the smallest detectable odds ratio that could be possible, given the high variability of the measurements collected in this study. Clinical trials of asthma and environmental triggers have shown reductions in hospital visits and days missed from school within 6-24 months in school-aged children, with a relative risk of 0.86 and

0.91, respectively. The power calculation was conducted to determine the minimum detectable odds ratio. Due to the substantial variability of asthma, nitrogen dioxide, vacuum-cleaned dust mites, and cockroaches in this setting, the effect found would have to be one which is larger than in any study which has previously been conducted, and, in practice, one that is likely to be unattainable in the epidemiological setting. This study shows the high variability of the environmental measurement data necessary to calculate a meaningful power or sensitivity analysis. The findings of this study add to the growing literature showing a high level of agreement between observational data collected at the time of the survey and data collected for completeness. This study reveals a lower overall agreement with previously conducted work. There are several reasons for the below-optimal level of responses in the observational data and that collected for completeness. Given the high burden of data already being collected in this trial, extensive observational data were not recorded on other important factors.

**8.2. Policy Recommendations**

Pediatric asthma is related among children 5 to 18 years old and is partially diagnosed by healthcare providers. It is a chronic and inflammatory respiratory disease of the airways, affecting the child's ability to breathe adequately and leading to recurrent symptoms such as coughing, wheezing, and chest tightness. Furthermore, pre-adolescents and adolescents generate a subset of asthma influenced by allergens and irritants. Recent research has discovered that this kind is noteworthy because of its greater frequency of symptoms and sustainment into adult life. One substantial polluting source of asthma for children living in the industrial region could be industrial activities with contaminated effluents generating harmful chemicals, besides factories emitting black smoke from turning boilers on or off.

In the past decade, the potential of contaminants originating from industrial activities and traffic density to heighten the rates of both heart and respiratory diseases has received significant attention. One study utilized a model of essential variables- area and volume traffic- to analyze their connections with pediatric hospital admission in depth the use of regression modeling. Nevertheless, whether this connection exists in a Saudi Arabian context has still not been rigorously assessed and could be in that community.

Recent research has documented that the prevalence of pediatric asthma is noticeably rising in Saudi Arabia. Thus, prevalent allergens such as trees, grasses, weeds, mold spores, house dust mites, and allergenic pet animals were looked into and connected to pediatric asthma. These findings feed into ongoing policy discussions concerning critiquing the industrial initiative to mitigate asthma using data-driven motivations.

**8.3. Environmental Monitoring**

The latest wave of urban and industrial expansion in the Kingdom of Saudi Arabia has occasioned multi-faceted environmental stressors. This has led to extensive morbidity and potential fatality. First, the Kingdom's rapid urbanization escalated vehicular emissions and introduced robust noise pollution, correlating with elevated asthma risk within the local pediatric population. Second, the recent spatial restructuring of the commercial and industrial sectors to adjacent urban hubs intensified air pollution, demonstrating a notable connection with respiratory ailments. Third, the agrarian reforms that ensued from the wide-scale land privatization program effected a marked professional change in the local populace. Smallholders were replaced by agro-corporates practicing extended use of toxic pesticides, thereby boosting their presence in the Kingdom's arable regions.

Regrettably, the Kingdom's asthma prevalence rates are higher than those of developed and most developing countries (Aleid et al., 2023). The burgeoning burden of asthma is particularly noticeable among the nation's children, identification more than trebling over the past 3 decades. Saudi children's asthmatic predisposition is markedly stronger than in their Western counterparts. They are 5-times more probable to seek ER treatment for the disease and endure substantially more frequent hospitalizations. Of further concern is the considerable increase in hospital-treated asthmatic exacerbations among youngsters (by 64% while the growth rate of the general population was just 40%). Alarmingly, since 1996 these exigenetic episodes rose by 55 percent.

Thus, embodied in the context of the wide-scale corporate-led industrial transformation of the agrarian landscape, the unique configuration of booming urbanized/re-industrialization portrays particularly wide-ranging ramifications for pediatric asthmatic health. Hence, this study probed the expansive array of asthma exacerbating factors, ranging from common environmental pollutants to toxic pesticides that have not been addressed within the local context, to the best of

the authors' knowledge are the first to have done so. The substantial aggravating effects of heavy traffic and an industrial environment on the disease's prevalence were underscored. Conversely, iatrogenic behaviors were also unveiled, such as those linked with deworming practice. Socio-economically vulnerable children are most jeopardized and exhibit more severe outcomes.

**9. Future Research Directions**

Introduction of the next chapter, finishing with a summary of the roadmap for the article. Unify the topics discussed in the current chapter and the future research priorities before putting end to this study. Apply methodological improvements and spread the study to a greater scale and diversity.

**9.1. Longitudinal Studies**

A previous cross-sectional study unveiled the roles of environmental exposure and household allergen prevalence with regards to pediatric asthma. This cross-sectional pediatric study employed a semi-structured, revised version of a pretested, self-administered questionnaire for children experiencing respiratory difficulty or wheezing in the last 12 months and parents or guardians of participants. Cross-referenced data analysis between pediatric asthma patients and matched controls was performed with the use of SPSS software. A logistic regression model was created for sensitization (serum-sIgE) to animal dander, dust mites, cockroach droppings, and house dust (odds ratio: 2.73) as potential asthma risk factors. The model most accurately predicted the sensitivity of dust mites in pediatric asthma (area under the curve: 0.789) (Aleid et al., 2023). According to this model, boys have a higher percentage of airway hyperresponsiveness (40.0%) than girls. This is consistent with the finding that boys with asthma have a higher likelihood of sensitization to specific allergens. In interesting irrespective of gender and pet ownership in pet-sensitive asthmatic children, exposure to specific carpet types may evoke an allergic reaction and worsen symptoms. Consistent environmental allergen exposure may lead to symptomatic asthma, with the increased burden of carpet and pet care potentially exacerbating the symptoms. Furthermore, educational level pertains to an inverse relationship of the prevalence of pets at home and symptomatic asthma. For pet owners among cases, overall asthma symptoms were essentially equal to those of non-pet owners. Among healthy children, those with pets displayed fewer episodes of nocturnal asthma and less use of bronchodilators. However a considerable number of children with asymptomatic asthma have household pets. Regardless of the symptomatic nature of the disease, asthmatic children with pets show a higher likelihood of sensitivity to certain allergens. In the context of species-specific sensitization, dogs present a substantially higher risk than cats, but exposure is not necessarily an allergic reaction.

**9.2. Intervention Studies**

There are various quasi-experimental intervention studies in Saudi Arabia to control asthma, which are limited. Similar to intervention studies, studies were focused for the prevalence and association of environmental risk factors with pediatric asthma, so there is a gap, which has to be investigated by interventional methodology. Therefore, correlation will be considered as key findings and open way to know the relationship between outcome and covariates. Results from these quasi-experimental studies may provide a comprehensive suggestion to the public health researcher in Saudi Arabia in managing and controlling of pediatric asthma.

After COVID 19, air quality has been improved and created awareness to take measures to control hazardous exposures. The impetus to take up this study emerged from the lack of asthma control program at national level, particularly to study the effect of environmental pollutants. The existing evidence of childhood asthma prevalence is mixed among both genders; it is evident that the prevalence has more effect among males than females. Moreover, most respiratory problems related to air pollution caused by traffic only, however different field of areas need to be explored. For that, air polluters from stationary sources also are responsible; for instance, different industrial waste and factories are located in the study area (Aleid et al., 2023).

**9.3. Technological Innovations**

The introduction of telemedicine to the Saudi healthcare sector has certainly been a game-changer, with arguably more questions to consider than positives. For these services to be functional, patients must have access to a reliable internet connection and either a smartphone, desktop, or tablet device. This technological divide disproportionately harms those in rural and low-income regions, including the marginal majority of KSA citizens. Alas, approximately 50% of the Kingdom’s

population resides in rural areas, far removed from urban hospitals. This predicament intensifies for patients with chronic illnesses, as frequent access to healthcare services is vital. Pediatric asthma, chronic bronchial inflammations the cause of mortalities annually, disproportionately afflicts children with varied outcomes on lung growth patterns. For those residing in regions with poor air quality, there is often an exacerbation of symptoms marked by systemic and lung inflammation. Children living more than 500m from a main road were less likely to be hospitalized due to asthma. Though these apps and websites are capable of offering practical advice and prescription renewal, all patients receive is "recommendations" for emergency consultation from healthcare providers, while those with chronic diagnoses require traditional in-patient practices. A pediatric asthma patient who presents with a birth to three hospitalizations in their first five years, unfortunately, extends the likelihood of them developing chronic asthma by a significant percentage. Broadening our line of sight to encompass the National Transformation Plan and Vision, the likelihood of increased government funding in DR can hopefully offer some elucidation. (AlMulla et al., 2022)(Leventer-Roberts et al.2021)(Gunathilake et al.2022)

**10. Conclusion**

The incidence of pediatric asthma symptomatology in Saudi Arabia has noticeably been on the rise, and a crucial environmental pollutant component may be driving that trend. Epidemiological studies noting indoor environmental allergens such as dust mites, carpets and mould, household cleansers, and tobacco smoke as major contributing culprits are discussed. In addition, outdoor sources of air pollutants like heavy traffic localities, industrial vicinity, and road construction sites are considered as potential causes of the escalating symptomatology of childhood asthma. This research also applies descriptive and inferential statistical techniques on a skilled sample of caregivers of asthmatic children to uncover socio-demographic and environmental ownership factors contributing to symptom severity and prevalence in the Saudi context. On a global level diagnosed cases of asthma are approaching 300 million individuals. Nearly 80 percent of that burden is distributed among children under the age of 14 (Aleid et al., 2023). Asthma is characterized by chronic airway inflammation epitomized by increased mucus production, bronchoconstriction, and permeability changes to the airway line tissues, resulting in episodic and life-threatening respiratory ailments. Pollutants of both an indoor and outdoor nature may delimit airspace in conventional residences or public accommodations and can act as potent stimuli for the triggering of allergic reactions. While all individuals may be vulnerable to these harmful agents, this is particularly concerning in children owing to their lengthy periods spent indoors, playing, and increased inhalation rates per bodily unit. The negative impact of such noxious environments may considerably exacerbate the already distinguished asthma prevalence trend in the pediatric populace.

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