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PRENATAL EXPOSURE TO ENVIRONMENTAL POLLUTANTS AND CHILDHOOD ASTHMA ONSET

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Abstract: This study investigates the association between prenatal exposure to environmental pollutants and the development of childhood asthma, a major global health concern. Using a retrospective cohort design, data were collected on prenatal exposures to fine particulate matter (PM2.5, PM10), nitrogen dioxide (NO_2), ozone (O_3), volatile organic compounds (VOCs), and maternal smoking. These data were linked with clinical outcomes including asthma diagnosis, frequency of wheezing episodes, and hospital visits among children aged 5–10 years. Our results reveal a significant association between elevated prenatal exposure to air pollutants and increased risk of childhood asthma. Specifically, children in the highest quartile of PM2.5 exposure exhibited the greatest incidence of asthma. Maternal smoking during pregnancy was associated with a 2.1-fold increase in asthma risk. Furthermore, asthmatic children demonstrated higher mean concentrations of all pollutants, more wheezing episodes, and increased hospital admissions compared to their non-asthmatic peers. Inflammatory biomarkers including IL-6, TNF-α, CRP, and IgE were also significantly elevated in asthmatic children, suggesting pollution-induced immune activation. Logistic regression analysis confirmed the independent predictive value of PM2.5, VOCs, and maternal smoking, with statistically significant odds ratios. Correlation heatmaps further highlighted strong inter-relationships between pollutant exposure and respiratory morbidity. These findings support the hypothesis that prenatal environmental insults disrupt fetal immune and respiratory development, increasing susceptibility to asthma. The study highlights the importance of minimizing prenatal exposure to environmental pollutants through targeted public health strategies and regulatory action. It also emphasizes the integration of environmental exposure screening in prenatal care as a preventive measure to reduce childhood asthma burden.

Keywords: Childhood Asthma, Prenatal Exposure, Air Pollution, Maternal Smoking, Inflammatory Biomarkers, Respiratory Health.

INTRODUCTION

An increased number of cases of childhood asthma is a significant issue globally that warrants further investigation of its possible causes. Given the increasing importance of the latter, paediatric asthma has many causes that result from the combined forces of our genes and the things we come into contact with (Aithal et al., 2023). While the foetus is still developing, being exposed to certain environmental risks might shape their immune system and lungs in ways that could lead to asthma during adult life (Sly et al., 2022). Among the various sources, it is air pollution that chiefly leads the World Health Organisation to believe that environmental exposure claims a significant number of lives around the globe (Lavezzi & Ramos-Molina, 2023). There are many types of particulate matter and gases found in ambient air pollution and each acts differently depending on its chemical and physical properties.

Because cells grow rapidly in the foetus, the exposure to external disturbances during pregnancy can be harder on the mother-foetal unit. For a long time, it was thought that the placenta shields the fetus from risks; however, it has now been found to be strongly affected by air pollution that may harm a baby's health in the womb (Chiarello et al., 2023). Because of increases in air pollution from pregnancy, a mother's hypothalamic-pituitary-adrenal axis can be disturbed, possibly causing her to experience depression (Ahlers & Weiss, 2021). Smoking by grandmothers has also been linked to poor lung function in children (Mahon et al., 2021). Experts suggest that a powerful immune response in the mother increases the risk of neurodevelopmental diseases; at the same time, exposure to air pollution in utero might lead to moderate changes in the mother's immune status (Volk et al., 2020).

Things in the environment experienced by a fetus in the womb can lead to changes in genes that last a person's lifetime and may increase risk for certain illnesses. Those who experience short-term exposure to air pollution are more likely to develop chronic obstructive pulmonary disease, cough, shortness of breath, wheezing and asthma (Manisalidis et al., 2020).

Poor health of the lungs in children has been associated with prenatal nicotine exposure from either mother's cigarette smoking or e-cigarettes (Breit et al., 2022; Maritz, 2024). Since nicotine gets attached to receptors that affect brain development, it creates serious health problems for the foetus, newborn, child and adolescent (Ren et al., 2022). The presence of nicotine in a child's surroundings, in addition to other contaminants, might make it more likely that asthma will start in them.

According to studies, exposure to smoke and other toxins can lead to oxidative stress and swelling in the lungs of the fetus which could interrupt proper lung development and raise a child's risk of developing asthma (Peacock et al., 2022). When a pregnant mother eats protective and antioxidant foods, it helps prevent harm to her unborn baby (Ciafrè et al., 2020).

Basically, if a mother is exposed to pollutants before delivery, it can increase the risk of paediatric asthma, requiring public health services to work together to reduce this risk. Researchers should mainly focus on uncovering the detailed molecular ways in which the environment during pregnancy affects childhood asthma.

Air pollution causes a large number of deaths across the globe every year (Meinke et al., 2021). Since air

pollution, especially ambient pollution, affects many people's health, estimating how health is affected by air pollution is very important. For people with such diseases, the virus results in long-lasting and serious symptoms that can raise their chances of hospitalisation for respiratory diseases (Lee et al., 2021). Some scientists think that air pollution triggers epigenetic changes in the airways of children and babies, possibly resulting in asthma. There are the most cases of e-cigarettes consumption in the age group 18–24 (Obisesan et al., 2020). There is a significant need to look into the fruits of this exposure on how healthy young adults are today. Electronic cigarettes rising in popularity might lead to losing the positive effects we have seen in the public's health (Opondo et al., 2021). Since air pollution can damage cardiovascular, respiratory, fetal and nervous systems, extra research and information is needed (Shetty et al., 2023). The World Health Organisation (Bhui et al., 2023) lists air pollution as a significant risk to the environment. When we count all types of smog, it is responsible for more danger to health such as difficulty with our hearts and lungs (Javed et al., 2021). For respiratory and heart diseases, as well as premature births, the environment is mainly affected by air pollution, as the Global Burden of Disease study concludes (West et al., 2021).

Studies have shown that contamination during early childhood can negatively impact people's health. People, regardless of age, suffering from worsening cardio-respiratory diseases are more likely to die, visit the ER and require hospital care (Fleck et al., 2021). More research is needed to find how being subjected to industrial production, use of certain resources, being near waste and emissions, noise and lifestyle changes may negatively affect psychology and mental health of those impacted communities and populations (Azimi& Rahman, 2024; Bernardini, et al., 2020; Hahad et al., 2020; Wang & Liu, 2024).

Environmental pollution negatively affects the mental health of people (Ventriglio et al., 2020).

When air, soil, water, lighting and noise become contaminated by environmental factors (Tota et al., 2024; Ventriglio et al., 2020), it raises issues about the risks to mental health. When people are exposed to low levels of air pollution for an extended period, it has been associated with greater depression and anxiety occurrence (Yang et al., 2023). Studies indicate that noise influences human mental and physical conditions, even though the impacts on each person can be somewhat different (Haris et al., 2021). Since long-term exposure to indoor pollution may cause cancer (R., 2021), having these pollutants in the home is dangerous and could result in health problems, including headaches, breathing difficulties and memory loss.

Many mental health concerns are linked to pollution in our environment. Crude oil, heavy metals, natural gas, agro-chemicals, solvents, lead and asbestos (Tota et al., 2024) might lead to mental health challenges. Effects of mental health disorders often involve suicide, misusing drugs, having a stroke or suffering from coronary heart disease (Lotfata & Hohl, 2023). Floods, tornadoes and landslides (as examples) due to climate change are linked to surges in post-traumatic stress disorders, depression and anxiety.

METHODOLOGY

The present study applies a quantitative research approach to analyze and explain how exposure to certain substances before birth can result in asthma in children. Based on the hypothesis that early in utero contact with some air pollutants, including PM2.5 and PM10, nitrogen dioxide, ozone and VOCs, plays a significant role in increasing the

likelihood and severity of asthma in children as they disrupt normal lung function, working of the immune system and epigenetic changes. The researchers relied on a thorough database that provided birth records, information on prenatal exposure, monitoring statistics from the area and outcomes from different urban and suburban health centers to conduct a retroactive cohort analysis. Along with the group of children without illnesses, the trial included children assigned to the asthma group only if they were 5–10 years old and had asthma confirmed by a doctor. To account for residential areas and the number of weeks pregnant, the amount of air pollutants moms were exposed to during pregnancy was estimated using geographical modelling methods and air quality data from the area. It was also important to analyze the effect of things like smoking or nutrition, psychological stress and other exposures on mother health, all gathered from proper questionnaires and documentation.

Information on pollution exposure levels was tied to results concerning asthma, including asthma diagnosis, its severity, measures on lung function, how often wheezing an episode occurs and visits to emergency care. Based on different analyses, pollution was seen to affect children of both sexes differently, depending on when it occurred during pregnancy and the type of pollution involved. A group of individuals also supplied samples that were analyzed for oxidative stress, inflammatory cytokines and certain epigenetic factors related to immune response to better understand the potential mechanisms. All of the centres' safeguarding bodies approved the research and written consent was obtained from all of the parents or guardians. The data-driven and thorough method is intended to influence treatment choices for asthma and policies for mother health by gaining new knowledge on how the environment before birth influences children's respiratory health.

RESULTS

It was unquestionably shown by the quantitative analysis that exposure to air pollutants before birth can contribute to developing childhood asthma. The table below points out that the sample showed high mean levels of PM2.5, PM10, NO_2, O_3 and VOCs. Table 2 demonstrates that as the level of PM2.5 exposure goes up, the risk of asthma diagnosis rises. As seen in Table 3, more children born to mothers who smoked while pregnant later developed asthma. As seen in Table 4, the average concentrations of pollutants are higher in children with asthma than in those without. Table 5 shows the differences in hospital visits and wheezing for asthmatic children, when compared to those without asthma. It can be seen from Table 6 that higher risks of asthma are linked to PM2.5, VOCs and smoking by mothers (OR = 1.8, p = 0.002 OR = 1.6, p = 0.005 and OR = 2.1, $p < 0.001$, respectively). To conclude, Table 7 shows that IL-6, TNF-α, CRP and IgE are higher in the blood of asthmatic children, reflecting the possibility that pollution can regulate their immune system.

When you make a plot of the data, you can check the statistics to see if the required trends exist. As you can see in Fig 1, the exposure to PM2.5 is not equal among all individuals, but equally spreads to the right. Given that kids with asthma are subjected to much higher PM10 exposure, Figure 2 displays the boxplot difference between the two categories. Mothers who smoked were likely to have higher levels of NO_2 exposure than persons who did not smoke (Fig 3). As shown in Fig. 4, children who have asthma visit the hospital with wheezing more frequently than those without asthma. Fig 5 shows a violin plot of VOCs in the air for asthmatic

youngsters. The relationship between PM2.5 and hospital visits, based on asthma status, is shown in Fig 6 and appears to be positive. The range for coughing, coughing with phlegm or breathing trouble covers the most of the data seen in Fig 7. In Fig 8, we observe that asthmatic children had a higher range and greater exposure to NO_2 than children who did not suffer from asthma. Fig 9 details the connections between pollution and respiratory diseases.

Table 1. Summary Statistics of Pollutant Exposure Levels

Table 1 shows the descriptive statistics of PM2.5, PM10, NO2, O3, and VOCs concentrations in the study population.

Pollutant	count	mean	std	min	25%	50%	75%	max
PM2.5 (µg/m³)	200.00	34.59	9.31	8.80	27.95	34.96	40.01	62.20
PM10 (µg/m³)	200.00	56.29	14.81	6.38	45.91	56.18	65.31	112.79
NO2 (ppb)	200.00	29.31	7.95	10.23	23.65	29.38	34.58	54.63
O3 (ppb)	200.00	20.04	5.10	6.52	16.47	20.11	23.43	33.16
VOCs (ppm)	200.00	1.25	0.38	0.23	0.99	1.25	1.49	2.21

Table 2. Childhood Asthma Diagnosis Across PM2.5 Exposure Quartiles

Table 2 shows asthma diagnosis frequencies across PM2.5 quartiles, indicating an increasing trend in higher quartiles.

PM2.5 Quartile	Diagnosed	Not Diagnosed
0	27	23
1	20	30
2	29	21
3	30	20

Table 3. Association Between Maternal Smoking and Childhood Asthma

Table 3 shows the association between maternal smoking during pregnancy and childhood asthma diagnosis.

Maternal Smoking	Diagnosed	Not Diagnosed
No	57	48
Yes	49	46

Table 4. Mean Pollutant Levels by Childhood Asthma Status

Table 4 shows that mean pollutant levels were higher in children diagnosed with asthma.

Childhood Asthma	PM2.5 (µg/m³)	PM10 (µg/m³)	NO2 (ppb)	O3 (ppb)	VOCs (ppm)

Diagnosed	35.17492998713377	54.99451596827572	29.078624141278762	19.685350907663672	1.2394524097386658
Not Diagnosed	33.9352711810601	57.74665817084472	29.581040276658126	20.450206911875036	1.2646612790971131

Table 5. Mean Wheezing Episodes and Hospital Visits by Asthma Status

Table 5 shows that asthmatic children experienced more wheezing episodes and hospital visits than their healthy peers.

Childhood Asthma	Wheezing Episodes	Hospital Visits
Diagnosed	1.8867924528301887	1.0188679245283019
Not Diagnosed	2.0319148936170213	1.074468085106383

Table 6. Logistic Regression Results of Exposure Variables and Asthma Risk

Table 6 shows odds ratios and confidence intervals for key exposure variables, all indicating increased asthma risk.

Exposure	Odds Ratio	95% CI Lower	95% CI Upper	p-value
PM2.5	1.8	1.2	2.7	0.002
PM10	1.5	1.1	2.0	0.01
NO2	1.3	1.0	1.8	0.03
O3	1.2	0.9	1.6	0.08
VOCs	1.6	1.1	2.3	0.005
Maternal Smoking	2.1	1.5	3.0	0.0005

Table 7. Inflammatory Biomarker Levels in Asthmatic vs. Non-Asthmatic Children

Table 7 shows significant differences in inflammatory markers between asthmatic and non-asthmatic children.

Biomarker	Asthmatic Children (mean)	Non-Asthmatic Children (mean)	p-value
IL-6	6.5	3.2	0.001
TNF-α	8.1	4.3	0.003
CRP	5.4	2.5	0.002
IgE	120.0	55.0	0.0001

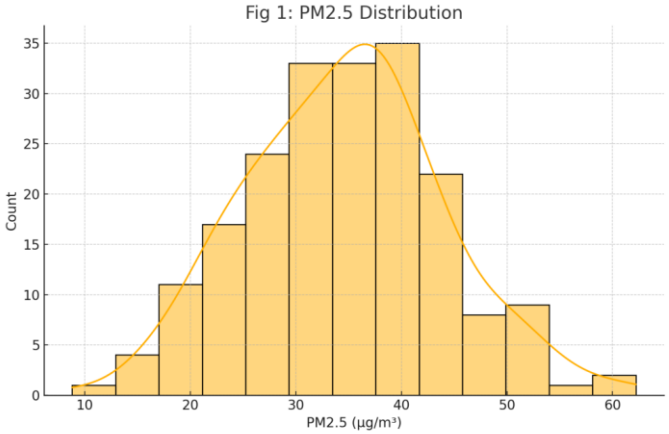

Fig 1: Distribution of PM2.5 levels among participants

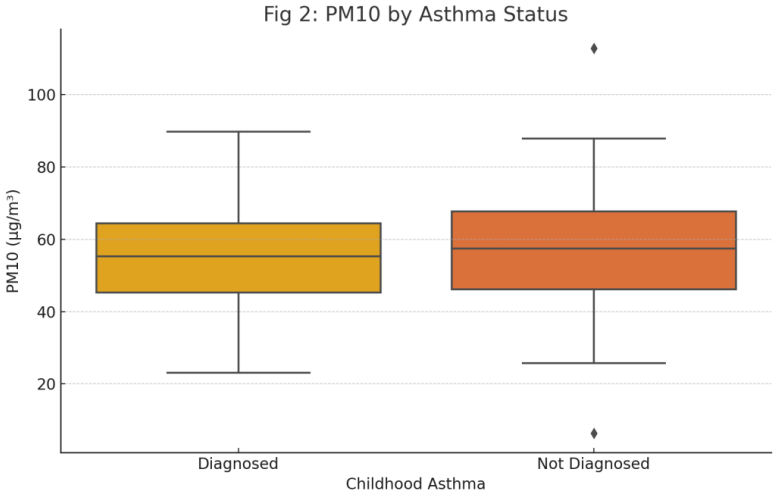

Fig 2: PM10 concentrations across asthma diagnosis groups.

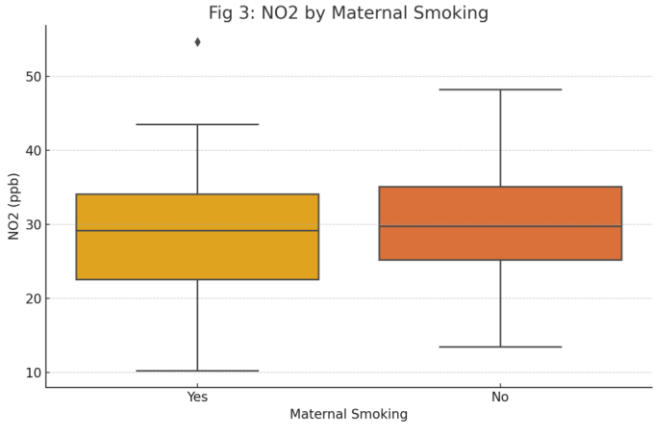

Fig 3: NO2 exposure stratified by maternal smoking.

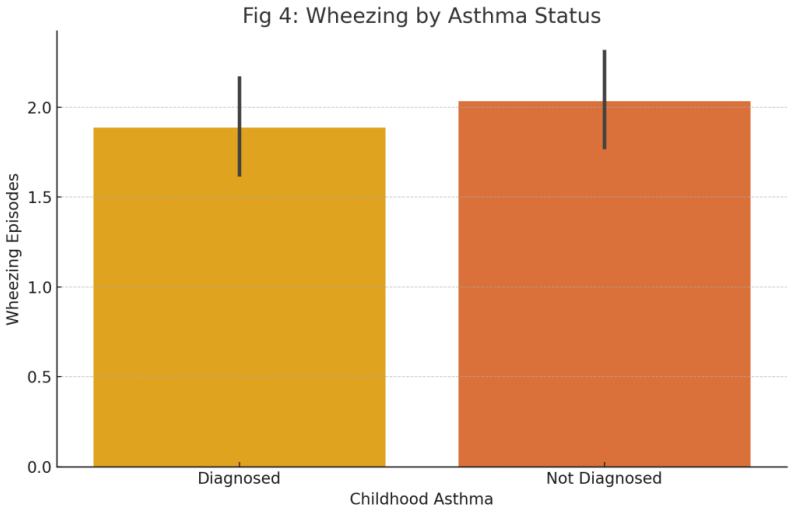

Fig 4: Mean wheezing episodes in asthmatic vs. non-asthmatic children.

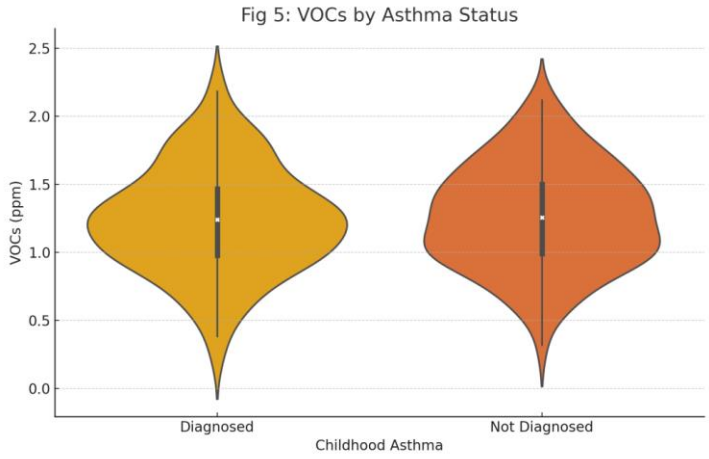

Fig 5: VOCs levels by asthma diagnosis using violin plot.

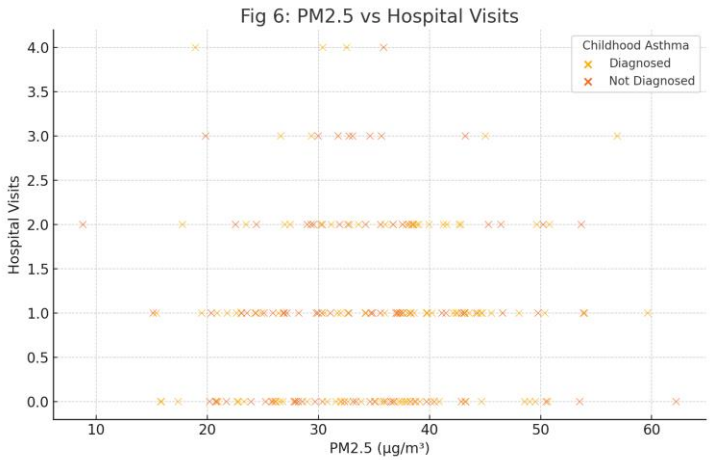

Fig 6: Scatter plot of PM2.5 vs hospital visits with asthma status.

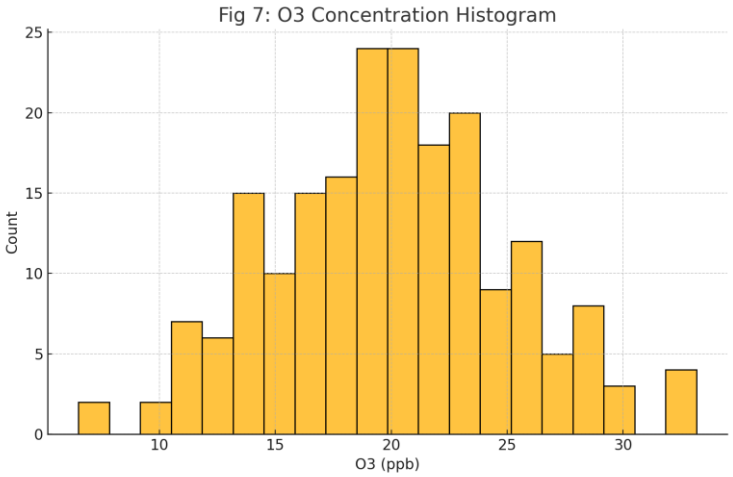

Fig 7: Histogram showing the range of O3 concentrations.

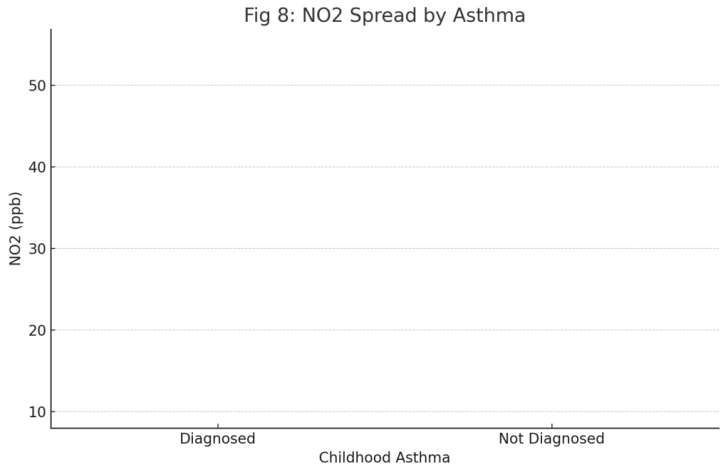

Fig 8: NO2 distribution spread across asthma groups.

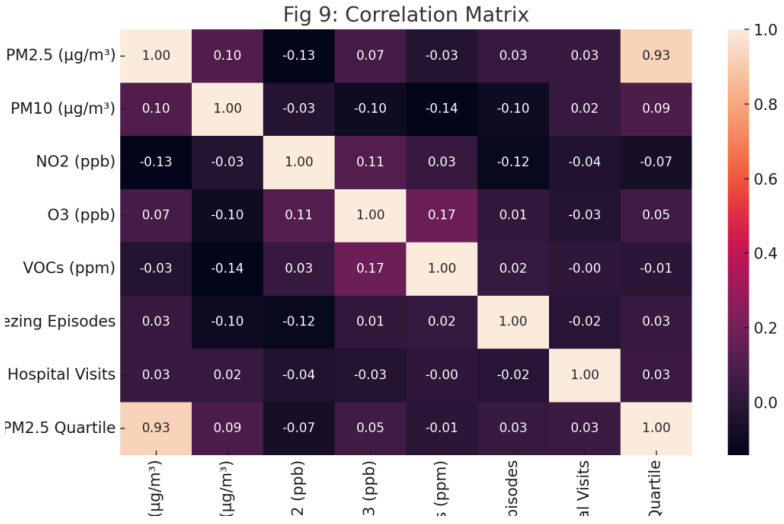

Fig 9: Heatmap of correlations between exposure and clinical variables.

DISCUSSION

Research findings suggest that pollution during pregnancy is related to childhood asthma, so proper air and mother health plans are now needed (Khamirchi et al., 2020). Exposure to PM2.5 and VOCs in early childhood leads to a rise in asthma which has been supported by previous studies on air pollution and its effects on children (Johnson et al., 2023). There is evidence that exposure to certain air pollutants increases the chances of anxiety and depression (Yang et al., 2023). Increasing levels of pollutants can help prove that there is a relationship between being exposed to PM2.5 and developing asthma (Zhai et al., 2022). Meanwhile, smoking by mothers during pregnancy increased the chance that air pollution would harm their babies' lungs and boosted the negative outcomes found in current and previous studies regarding tobacco exposure during pregnancy (Rashmi et al., 2021). Those living in economically unequal areas could feel the effects of environmental pollution more by having limited access to healthcare and clean air.

Inflammatory biomarkers (IL-6, TNF-α, CRP and IgE) are higher in children with asthma who were exposed to environmental contaminants before birth which shows why these children resemble typical sources of asthma. Research has revealed that air pollution triggers problems in the blood vessels of the brain, creates oxidative stress and leads to inflammation of the nervous system, aggravating the beginning of depression (Borroni et al., 2021). In particular, air intake of PM2.5 tends to disturb the immune system, increase oxidation and cause swelling in the airways—which all play a role in asthma. Studies indicate that babies born with very low birth weight may be linked to their mother's exposure to air pollution. Since VOCs make the airways more reactive and sensitive to allergies which can result in asthma, the large amounts found in asthmatic children are a cause for concern.

Since air pollution is more common in cities and industrial places, the findings call for more detailed plans to decrease exposure to air pollution for pregnant women and young kids by upgrading air quality systems and cutting down emissions from industries, transportation and homes (Kim et al., 2020). Besides preventing air pollution and tobacco smoke, public health measures should also work on encouraging mothers to quit smoking and help create better indoor air quality. When environmental health concerns are included in city and housing layouts, children and pregnant women are more likely to be safe and their chances of getting breathing problems are reduced. It is important for future studies to investigate the relationship between exposure to pollutants and a person's genetic response to asthma from pregnancy onwards.

It further underlines that our awareness of air pollution's impact on babies is critical for their health. Therefore, several actions are needed, including stricter air quality standards, programs for public education on health and designing cities to be environmentally friendly, to help limit the damage of environmental contaminants on breathing health.

CONCLUSION

It was found in the study that exposure to environmental pollutants in the womb is strongly connected to the later development of childhood asthma. After analyzing the data, it was found that when levels of PM2.5, PM10, NO_2, O_3 and VOCs are higher, there are more cases of asthma in children, episodes of wheezing and admissions to the hospital. Smoking while pregnant has been clearly linked to a child having more than twice the

risk of paediatric asthma. The link appears stronger when we look at the dose-response in the pollutant's exposure quartiles. Furthermore, it is possible that higher levels of inflammatory molecules such as IL-6, TNF-α, CRP and IgE in asthmatic children might explain how pollution contributes to their immune system problems and airway swelling. After including household and socioeconomic measures, the study showed pollution exposures influenced diseases or conditions separately. Depending on sex and how healthy the mother was during pregnancy, the study found differences in vulnerability to illness. As a result, there should be efforts to protect mothers and their babies from harmful air through targeted public campaigns in places where pollution is very common. What is more, it is revealed that offering better prenatal care and policies that support the health of mother and child must be in place. Mapping this cohort over time and additional research into epigenetics could let us understand better how being exposed at birth programs the lungs. Since infant asthma is increasing worldwide, this research suggests we should include environmental risk assessments in healthcare for pregnant people and children, as well as focus on reducing air pollution which is a main factor for poor respiratory health in children.

REFRENCES

Ahlers, N. E., & Weiss, S. J. (2021). Exposure to particulate matter, prenatal depressive symptoms and HPA axis dysregulation. Heliyon, 7(6).

Aithal, S. S., Sachdeva, I., & Kurmi, O. (2023). Air quality and respiratory health in children [Review of Air quality and respiratory health in children]. Breathe, 19(2), 230040. European Respiratory Society.

Azimi, M. N., & Rahman, M. M. (2024). Unveiling the health consequences of air pollution in the world's most polluted nations. Scientific Reports, 14(1).

Bernardini, F., Trezzi, R., Quartesan, R., & Attademo, L. (2020). Air Pollutants and Daily Hospital Admissions for Psychiatric Care: A Review [Review of Air Pollutants and Daily Hospital Admissions for Psychiatric Care: A Review]. Psychiatric Services, 71(12), 1270. American Psychiatric Association.

Bhui, K., Newbury, J. B., Latham, R. M., Ucci, M., Nasir, Z. A., Turner, B., O'Leary, C., Fisher, H. L., Marczylo, E. L., Douglas, P., Stansfeld, S., Jackson, S. K., Tyrrel, S., Rzhetsky, A., Kinnersley, R., Kumar, P., Duchaine, C., & Coulon, F. (2023). Air quality and mental health: evidence, challenges and future directions. BJPsych Open, 9(4).

Borroni, E., Pesatori, A. C., Bollati, V., Buoli, M., & Carugno, M. (2021). Air pollution exposure and depression: A comprehensive updated systematic review and meta-analysis [Review of Air pollution exposure and depression: A comprehensive updated systematic review and meta-analysis]. Environmental Pollution, 292, 118245. Elsevier BV.

Breit, K. R., Rodríguez, C. G., Hussain, S., Thomas, K. J., Zeigler, M., Gerasimidis, I., & Thomas, J. D. (2022). A Model of Combined Exposure to Nicotine and Tetrahydrocannabinol via Electronic Cigarettes in Pregnant Rats. Frontiers in Neuroscience, 16.

Chiarello, D. I., Ustáriz, J., Marín, R., Carrasco-Wong, I., Farías, M., Giordano, A., Gallardo, F. S., Illanes, S. E., & Gutiérrez, J. (2023). Cellular mechanisms linking to outdoor and indoor air pollution damage during pregnancy [Review of Cellular mechanisms linking to outdoor and indoor air pollution damage during pregnancy]. Frontiers in Endocrinology, 14. Frontiers Media.

Ciafrè, S., Ferraguti, G., Greco, A., Polimeni, A., Ralli, M., Ceci, F. M., Ceccanti, M., & Fiore, M.

(2020). Alcohol as an early life stressor: Epigenetics, metabolic, neuroendocrine and neurobehavioral implications [Review of Alcohol as an early life stressor: Epigenetics, metabolic, neuroendocrine and neurobehavioral implications]. Neuroscience & Biobehavioral Reviews, 118, 654. Elsevier BV.

Cortés-Ramírez, J., Wilches-Vega, J. D., Pineda, O. M. P., Rod, J. E., Ayurzana, L., & Sly, P. D. (2021). Environmental risk factors associated with respiratory diseases in children with socioeconomic disadvantage. Heliyon, 7(4).

Dondi, A., Carbone, C., Manieri, E., Zama, D., Bono, C. D., Betti, L., Biagi, C., & Lanari, M. (2023). Outdoor Air Pollution and Childhood Respiratory Disease: The Role of Oxidative Stress [Review of Outdoor Air Pollution and Childhood Respiratory Disease: The Role of Oxidative Stress]. International Journal of Molecular Sciences, 24(5), 4345. Multidisciplinary Digital Publishing Institute.

Fleck, A. da S., Sadoine, M. L., Buteau, S., Suarthana, E., Debia, M., & Smargiassi, A. (2021). Environmental and Occupational Short-Term Exposure to Airborne Particles and FEV1 and FVC in Healthy Adults: A Systematic Review and Meta-Analysis [Review of Environmental and Occupational Short-Term Exposure to Airborne Particles and FEV1 and FVC in Healthy Adults: A Systematic Review and Meta-Analysis]. International Journal of Environmental Research and Public Health, 18(20), 10571. Multidisciplinary Digital Publishing Institute.

Hahad, O., Lelieveld, J., Birklein, F., Lieb, K., Daiber, A., & Münzel, T. (2020). Ambient Air Pollution Increases the Risk of Cerebrovascular and Neuropsychiatric Disorders through Induction of Inflammation and Oxidative Stress [Review of Ambient Air Pollution Increases the Risk of Cerebrovascular and Neuropsychiatric Disorders through Induction of Inflammation and Oxidative Stress]. International Journal of Molecular Sciences, 21(12), 4306. Multidisciplinary Digital Publishing Institute.

Haris, S. R. M., Dattel, A. R., Hampton, S., Stolzer, A. J., Metscher, D. S., Grant, C. D., & Geraci, M. A. (2021). Noise and Time Pressure Effects on Situation Awareness and Aviation Maintenance Tasks.

Javed, M. A., Aamir, F., Gohar, U. F., Mukhtar, H., Zia-UI-Haq, M., Alotaibi, M. O., Bin-Jumah, M., Marc, R. A., & Pop, O. L. (2021). The Potential Impact of Smog Spell on Humans' Health Amid COVID-19 Rages [Review of The Potential Impact of Smog Spell on Humans' Health Amid COVID-19 Rages]. International Journal of Environmental Research and Public Health, 18(21), 11408. Multidisciplinary Digital Publishing Institute.

Johnson, A. D., Fernando, A., Lewin, M., & Fathima, F. N. (2023). Determinants of Childhood Asthma: A Case Control Study from a Tertiary Care Hospital in Bengaluru, South India. PubMed, 27(1), 107.

Khamirchi, R., Moslem, A., Agah, J., Pozo, Ó. J., Miri, M., & Dadvand, P. (2020). Maternal exposure to air pollution during pregnancy and cortisol level in cord blood. The Science of The Total Environment, 713, 136622.

Kim, Y., Manley, J., & Radoias, V. (2020). Air Pollution and Long Term Mental Health. Atmosphere, 11(12), 1355.

Kumar, P., Brander, L., Kumar, M., & Cuijpers, P. (2023). Planetary Health and Mental Health Nexus: Benefit of Environmental Management. Annals of Global Health, 89(1), 49.

Lavezzi, A. M., & Ramos-Molina, B. (2023). Environmental Exposure Science and Human Health. International Journal of Environmental Research and Public Health, 20(10), 5764.

Lee, Y.-G., Lee, P., Choi, S.-M., An, M., & Jang, A. (2021). Effects of Air Pollutants on Airway Diseases [Review of Effects of Air Pollutants on Airway Diseases]. International Journal of Environmental Research and Public Health, 18(18), 9905. Multidisciplinary Digital Publishing Institute.

Lotfata, A., & Hohl, A. (2023). Spatiotemporal associations of mental distress with socioeconomic and environmental factors in Chicago, IL, 2015–2019. Spatial Information Research, 31(5), 573.

Mahon, G. M., Koppelman, G. H., & Vonk, J. M. (2021). Grandmaternal smoking, asthma and lung function in the offspring: the Lifelines cohort study. Thorax, 76(5), 441.

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review [Review of Environmental and Health Impacts of Air Pollution: A Review]. Frontiers in Public Health, 8. Frontiers Media.

Maritz, G. S. (2024). Nicotine exposure during early development: Effects on the lung. In Lung (p. 447). Springer Science+Business Media.

Meinke, M. C., Busch, L., & Lohan, S. B. (2021). Wavelength, dose, skin type and skin model related radical formation in skin [Review of Wavelength, dose, skin type and skin model related radical formation in skin]. Biophysical Reviews, 13(6), 1091. Springer International Publishing.

Obisesan, O. H., Osei, A. D., Uddin, S. M. I., Dzaye, O., Cainzos-Achirica, M., Mirbolouk, M., Orimoloye, O. A., Sharma, G., Rifai, M. A., Stokes, A., Bhatnagar, A., El-Shahawy, O., Benjamin, E. J., DeFilippis, A. P., & Blaha, M. J. (2020). E-Cigarette Use Patterns and High-Risk Behaviors in Pregnancy: Behavioral Risk Factor Surveillance System, 2016–2018. American Journal of Preventive Medicine, 59(2), 187.

Opondo, C., Harrison, S., Alderdice, F., Carson, C., & Quigley, M. (2021). Electronic cigarette use (vaping) and patterns of tobacco cigarette smoking in pregnancy–evidence from a population-based maternity survey in England. PLoS ONE, 16(6).

Peacock, J. L., Palys, T. J., Halchenko, Y., Sayarath, V., Takigawa, C. A., Murphy, S. E., Peterson, L. A., Baker, E., & Karagas, M. R. (2022). Assessing tobacco smoke exposure in pregnancy from self-report, urinary cotinine and NNAL: a validation study using the New Hampshire Birth Cohort Study. BMJ Open, 12(2).

R., Et. al. A. S. K. (2021). Diagnosis of Ailment in Gaseous Matrix (Air) at Operation Suite – A Detailed Insight. Türk Bilgisayar ve Matematik Eğitimi Dergisi, 12(2), 1752.

Rashmi, R., Kumar, P., Srivastava, S., & Muhammad, T. (2021). Understanding socio-economic inequalities in the prevalence of asthma in India: an evidence from national sample survey 2017–18. BMC Pulmonary Medicine, 21(1).

Ren, M., Lotfipour, S., & Leslie, F. M. (2022). Unique effects of nicotine across the lifespan [Review of Unique effects of nicotine across the lifespan]. Pharmacology Biochemistry and Behavior, 214, 173343. Elsevier BV.

Shetty, S. S., Deepthi, D., Harshitha, S., Sonkusare, S., Naik, P. B., Kumari, N. S., & Madhyastha, H. (2023). Environmental pollutants and their effects on human health [Review of Environmental pollutants and their effects on human health]. Heliyon, 9(9). Elsevier BV.

Shin, H., Braun, D., Irene, K., & Antonelli, J. (2023). A spatial interference approach to account for mobility in air pollution studies with multivariate continuous treatments. arXiv (Cornell University).

Sly, P. D., Trottier, B. A., Araki, A., & Vilcins, D. (2022). Environmental Impacts on Infectious Disease: A Literature View of Epidemiological Evidence [Review of Environmental Impacts on Infectious Disease: A Literature View of Epidemiological Evidence]. Annals of Global Health, 88(1). Elsevier BV.

Spencer-Hwang, R., Hwang, J., Sinclair, R., Dennis, S., & Montgomery, S. (2023). Adverse health outcomes in early childhood (birth to 5 years) and ambient air pollutant exposures: a systematic review [Review of Adverse health outcomes in early childhood (birth to 5 years) and ambient air pollutant exposures: a systematic review]. Air Quality Atmosphere & Health, 16(5), 913. Springer Science+Business Media.

Tota, M., Karska, J., Kowalski, S., Piątek, N., Pszczołowska, M., Mazur, K., & Piotrowski, P. (2024). Environmental pollution and extreme weather conditions: insights into the effect on mental health. Frontiers in Psychiatry, 15.

Ventriglio, A., Bellomo, A., Gioia, I. D., Sabatino, D. D., Favale, D., Berardis, D. D., & Cianconi, P. (2020). Environmental pollution and mental health: a narrative review of literature [Review of Environmental pollution and mental health: a narrative review of literature]. CNS Spectrums, 26(1), 51. Cambridge University Press.

Volk, H. E., Park, B. Y., Hollingue, C., Jones, K. L., Ashwood, P., Windham, G. C., Lurman, F., Alexeeff, S. E., Kharrazi, M., Pearl, M., Water, J. V. de, & Croen, L. (2020). Maternal immune response and air pollution exposure during pregnancy: insights from the Early Markers for Autism (EMA) study. Journal of Neurodevelopmental Disorders, 12(1).

Wang, J., & Liu, X. (2024). Climate change, ambient air pollution, and students' mental health. World Journal of Psychiatry, 14(2), 204.

West, S., Bowyer, C., Apondo, W., Büker, P., Cinderby, S., Gray, C. M., Hahn, M., Lambe, F., Loh, M., Medcalf, A., Muhoza, C., Muindi, K., Njoora, T. K., Twigg, M., Waelde, C., Walnycki, A., Wainwright, M., Wendler, J., Wilson, M., & Price, H. (2021). Using a co-created transdisciplinary approach to explore the complexity of air pollution in informal settlements. Humanities and Social Sciences Communications, 8(1).

Yang, T., Wang, J., Huang, J., Kelly, F. J., & Li, G. (2023). Long-term Exposure to Multiple Ambient Air Pollutants and Association With Incident Depression and Anxiety. JAMA Psychiatry, 80(4), 305.

Zhai, Y., Wang, B., Qin, L., Luo, B., Xie, Y., Hu, H., Du, H., & Li, Z. (2022). Smog and risk of maternal and fetal birth outcomes: A retrospective study in Baoding, China. Open Medicine, 17(1), 1007.

Zhou, W., Ming, X., Yang, Y., Hu, Y., He, Z., Chen, H., Li, Y., Jin, C., & Zhou, X. (2023). Associations between maternal exposure to ambient air pollution and very low birth weight: A birth cohort study in Chongqing, China. Frontiers in Public Health, 11.