The Impact Of Maternal Diet, Lifestyle, & Environmental Exposures During Pregnancy On Autism Spectrum Disorder In Children

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A thesis submitted to the Department of Biotechnology in partial fulfillment of the requirements for the degree of Master's of Science in Biotechnology

Department of Biotechnology
BRAC University
March 2026

Declaration

It is hereby declared that

1. The thesis submitted is my/our original work while completing my degree at BRAC University.

2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.

3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.

4. I have acknowledged all main sources of help.

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Approval

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Abstract

Autism Spectrum Disorder (ASD) is a complicated illness that is classified as a neurodevelopmental disorder that is influenced by a variety of factors, including genetics, environment, nutrition, and lifestyle. There is an increasing amount of evidence that suggests that the food and lifestyle behaviors of the mother, as well as the environmental exposures to which she is subjected during pregnancy, have a significant influence on determining how the brain of the fetus develops and may even be a contributing factor to the risk of autism. This study investigates the effects of prenatal dietary patterns, micronutrient deficiencies, metabolic conditions, maternal stress, physical activity, exposure to toxins, air pollution, heavy metals, and household dangers on a global scale. The review also explores how these elements interact with one another to affect the development of autism spectrum disorder. Due to its high population density and vulnerability to environmental threats, Bangladesh confronts several specific problems. Among them are starvation, contamination by heavy metals, industrial pollution, widespread pesticide use, degraded air quality in urban areas, and inadequate waste management. These elements may lead to an inequitable rise in the likelihood that children will acquire developmental problems. This analysis synthesizes literature from both national and global contexts to identify the most important factors that determine the risk of autism in relation to the mother's health and environment. The review also highlights research gaps in Bangladesh and offers potential avenues for future scientific study and legislation. According to the findings, to reduce the incidence of ASD, there is a need for extensive maternal health programs, more control over the environment, improved prenatal nutrition initiatives, and interventions at the community level. To effectively detect and decrease the risk factors of autism in the populations of South Asia, it is necessary to take important efforts, such as enhancing data collection and participating in epidemiological research in Bangladesh.

Keywords: Autism, maternal diet, pregnancy lifestyle, environmental exposure, Bangladesh, neurodevelopment, fetal brain development, micronutrients, pollution, developmental disorders.

Dedication

This thesis is dedicated to the Almighty Allah, whose blessings, guidance, and mercy have enabled me to pursue and complete this research journey.

I also dedicate this work to my parents as well as my beloved husband, whose unconditional love, sacrifices, and constant encouragement have shaped my life and given me strength in every challenge.

A special note of gratitude goes to my siblings, whose support and motivation have always inspired me to keep moving forward.

Israt Jahan
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March, 2026

Acknowledgement

I am profoundly grateful to the highest God for enabling me to undertake this research.

I extend my sincere thanks to Dr. Iftekhar Bin Naser, Chairperson & Associate Professor, Department of Biotechnology at BRAC University, for allowing me to pursue my studies within the department.

My deepest gratitude goes to my supervisor, Dr. Munima Haque, Associate Professor, Department of Biotechnology, BRAC University, for her invaluable support, guidance, and insight throughout my research journey.

I am also sincerely thankful to my family, especially my parents, for their unwavering love and support, which have been my greatest source of strength.

Israt Jahan

March, 2026

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List of Acronyms

- **ASD** – Autism Spectrum Disorder
- **ANC** – Antenatal
- **Care BMI** – Body Mass Index
- **BTEX** – Benzene, Toluene, Ethylbenzene, Xylene
- **CO** – Carbon Monoxide
- **DHA** – Docosahexaenoic Acid
- **DNA** – Deoxyribonucleic Acid
- **EPA** – Environmental Protection Agency
- **EPA** (Omega-3) – Eicosapentaenoic Acid
- **FAO** – Food and Agriculture Organization
- **GDM** – Gestational Diabetes Mellitus
- **HPA** – Hypothalamic–Pituitary–Adrenal Axis
- **Hg** – Mercury
- **IL-6** – Interleukin-6
- **IQ** – Intelligence Quotient
- **ND2** – NADH Dehydrogenase 2 Gene
- **NIPORT** – National Institute of Population Research and Training
- **PM2.5** – Fine Particulate Matter (≤2.5 µm)
- **PM10** – Particulate Matter (≤10 µm)
- **RNA** – Ribonucleic Acid
- **UV-B** – Ultraviolet-B Radiation
- **VOC** – Volatile Organic Compounds
- **WHO** – World Health Organization
- **M-CHAT**-Modified Checklist for Autism in Toddlers
- **ADOS-2**-Autism Diagnostic Observation Schedule, 2nd Edition
- **CARS-2** -Childhood Autism Rating Scale, 2nd Edition

Chapter 1: Introduction

1.1 Background of Autism and Maternal Influences

Autism Spectrum Disorder (ASD) is a multifaceted neurodevelopmental disorder marked by enduring difficulties in social communication, limited preferences, and repetitive behavioral patterns (American Psychiatric Association, 2013). The global prevalence of ASD has significantly risen in recent decades, primarily attributable to enhanced diagnostic criteria, increased public awareness, and improved screening techniques (Maenner et al., 2021).
While genetic factors possess a significant role in the etiology of ASD, recent research underscores the significance of prenatal environmental and maternal influences. Maternal nutrition, lifestyle choices, stress levels, metabolic disorders, and environmental exposures during pregnancy can influence early fetal brain development and may alter the risk of autism spectrum disorder (Lyall et al., 2017; Modabbernia et al., 2017).

Fetal neurodevelopment is especially susceptible to maternal physiological alterations and environmental variables during gestation. Nutritional intake, micronutrient status, maternal cortisol levels, inflammation, and exposure to toxins all affect the growth of neurons, the activity of neurotransmitters, and the formation of synapses (Hertz-Picciotto et al., 2018). International research consistently indicates that maternal deficiencies in folate, iron, vitamin D, and omega-3 fatty acids can adversely affect neurogenesis, myelination, and cognitive development (Bianchi & Phillips, 2020). Exposure to air pollution, heavy metals, pesticides, and environmental contaminants may lead to oxidative stress or interfere with neural signaling pathways during fetal development (Kalkbrenner et al., 2014; Raz et al., 2015; Christensen et al., 2019). These findings bolster the notion that pregnancy constitutes a critical period wherein alterable maternal factors directly impact enduring neurodevelopmental outcomes, including the chance of ASD.

Figure 01: Signs of Autism in Babies and Toddlers

Medically Recognized Types of Autism (DSM-5)

The medical system no longer divides autism into types like Asperger's or PDD-NOS. Instead, they use:

Autism Spectrum Disorder (ASD) Level 1 – Requires support (mild, high-functioning autism)

ASD Level 2 – Requires substantial support (moderate autism)

ASD Level 3 – Requires very substantial support (severe autism; speech and intellectual disabilities)

Nutrition and lifestyle factors may contribute to where a child falls on this severity scale. Globally, prenatal risk factors for ASD encompass maternal obesity, diabetes, suboptimal diet, micronutrient deficiency, elevated psychosocial stress, exposure to tobacco smoke, and inflammation connected to infection (Surén et al., 2013). Environmental factors, which include particulate matter (PM2.5), arsenic, mercury, and lead contamination, have been extensively linked to impaired fetal brain development. These studies collectively illustrate that the risk of Autism Spectrum Disorder (ASD) is affected not only by genetic predispositions but also by a complex array of prenatal exposures operating through biological, nutritional, and environmental mechanisms.

In Bangladesh, these risk factors are especially worrisome because they overlap. Maternal malnutrition and deficiencies in micronutrients are still very common, especially in rural and low-income areas. Many pregnant women do not consume a lot of different foods. They often eat a lot of rice and don't have access to good proteins, fruits, vegetables, and fortified foods.

In big cities like Dhaka, Gazipur, and Chattogram, environmental exposures are very high. For example, air pollution often goes above WHO safety limits. Heavy metal pollution, such as arsenic and lead in groundwater, makes the environmental risk for pregnant women even worse. Moreover, significant psychosocial stress stemming from poverty, overcrowding, domestic obligations, and restricted access to prenatal care renders numerous Bangladeshi women vulnerable during their pregnancy. Even though more people in cities are being diagnosed with ASD, there isn't much national-level data (Zaman et al., 2021). Despite increasing apprehension, no extensive review has yet consolidated the impacts of maternal diet, lifestyle, and environmental factors on ASD within the Bangladeshi population. This thesis seeks to address that significant knowledge deficiency.

1.2 Significance of the Study

Learning about the prenatal determinants of ASD is crucial, as maternal health and environmental exposures are among the most alterable factors affecting fetal neurodevelopment. Research across various populations indicates that interventions during pregnancy—such as nutritional supplementation, enhancement of maternal lifestyle, and decreased exposure to detrimental environmental toxins—may mitigate risks linked to ASD and other developmental disorders (Huguet et al., 2020). Studying these factors is especially important for Bangladesh, where pregnant women often have to deal with multiple problems at once, such as poor nutrition, pollution, stress, and not being able to get good medical care.

Bangladesh has many problems with maternal nutrition, including not eating a diverse diet, high anemia, insufficient protein, and inadequate intake of important micronutrients such as iron, zinc, folate, and vitamin D (National Institute of Population Research, 2020). These nutritional deficiencies impede neuronal development and may increase susceptibility to ASD. Environmental pollution is another danger. Unfortunately, Bangladesh is often one of the countries with the worst air quality in the world. High levels of PM2.5, industrial emissions, vehicle exhaust, and brick-kiln smoke can cross the placental barrier and affect fetal brain development (Perera et al., 2019). Water pollution, especially arsenic in groundwater, has been associated with cognitive impairment and neurobehavioral deficits in Bangladeshi children (Rahman et al., 2017).

Living in a city, with all the noise, stress from work, and lack of social support, can also raise the stress levels of mothers, which is known to be a factor in bad neurodevelopmental outcomes (Beversdorf et al., 2018). In the meantime, people who live in rural areas have problems like not having enough prenatal care services, not having enough money, and health disparities that never go away. Even with these risks, most of the research on ASD in Bangladesh has been about how common it is and how hard it is to diagnose, not about what causes it before birth. This study offers essential scientific insight by amalgamating global evidence with maternal risk factors specific to Bangladesh. It offers a unique viewpoint to the literature by pinpointing maternal nutritional, lifestyle, and environmental factors that may affect ASD development in these circumstances.

1.3 Objectives of the Review

The main objective of this review is to consolidate global research on prenatal nutritional, lifestyle, and environmental factors affecting ASD and to contextualize these findings for Bangladesh. The study's primary objective is to investigate the impact of maternal nutrition on autism risk, focusing on micronutrients including folate, vitamin D, iron, and omega-3 fatty acids. This entails assessing global data concerning malnutrition, metabolic disorders, and dietary deficiencies, in addition to analyzing the eating habits among pregnant women in Bangladesh. Second, the review looks at maternal lifestyle factors that are known to affect fetal neurodevelopment, such as stress, physical activity, sleep quality, depression, exposure to tobacco smoke, household air pollution, and substance or medication use.

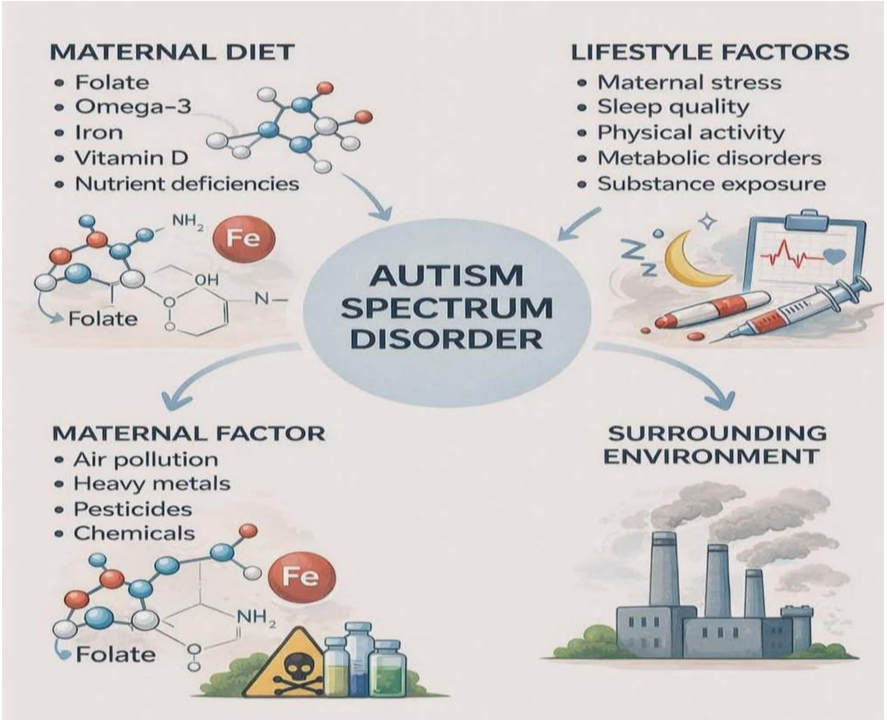

Figure 2: Pathways Linking Maternal Nutrition, Lifestyle, and Environment to ASD Risk

Third, the study analyzes environmental and surrounding factors that may influence ASD risk, such as air pollution (PM2.5 and PM10), heavy metals (lead, mercury, arsenic), pesticides, plastics, household toxins, indoor cooking fuel, and industrial pollution affecting local communities. Fourth, the review identifies Bangladesh-specific vulnerabilities, including nutritional deficiencies, environmental contaminants, socioeconomic barriers, and healthcare system limitations that may heighten prenatal risk.

Chapter 2: Maternal Diet and Nutritional Determinants

2.1 Macronutrients and Micronutrients

Vitamin D deficiency is widespread among pregnant women and children in Bangladesh, rendering it a critical factor in neurodevelopmental vulnerability, including autism. A case–control study conducted in Dhaka indicated that 80% of children with ASD and 66% of typically developing children exhibited deficient or insufficient vitamin D levels, with ASD cases displaying slightly lower mean concentrations (Afroz, 2021). Another investigation from Bangladesh looked at mitochondrial ND2 gene variants and found that they were linked to changes in the levels of vitamin D and thyroid hormones in children with ASD. This suggests that vitamin D may work with genetic susceptibility to affect the risk of autism (Rahman et al., 2025). In addition to an autism diagnosis, vitamin D status was demonstrated to affect early behavioral, emotional, and linguistic development in Bangladeshi infants, especially those residing in urban slums, where vitamin D deficiency correlated with inadequate temperament regulation and delayed language comprehension (Tofail et al., 2019). Maternal vitamin D deficiency is prevalent in Bangladesh. A rural cohort study revealed that 64.5% of pregnant women exhibited vitamin D deficiency or insufficiency, notably among younger women, those with limited sun exposure, and those lacking dietary diversity (Ahmed et al., 2021). Another national review identified hypovitaminosis D as a “silent maternal epidemic” in Bangladesh, indicating that 66–94% of pregnant women possess insufficient vitamin D levels attributable to pollution, insufficient dietary sources, cultural clothing practices, and restricted supplementation (Islam et al., 2022). These findings from Bangladesh suggest that although vitamin D deficiency may not directly induce autism, it establishes a biological susceptibility that can adversely impact fetal brain development, particularly when coupled with additional risk factors such as environmental toxins, maternal stress, and genetic predispositions.

Maternal nutrition during gestation is a pivotal factor in fetal brain development, affecting neurogenesis, synaptic formation, epigenetic programming, and overall neurodevelopmental outcomes (Koletzko et al., 2019). Recent research seems to show that dietary imbalance, micronutrient deficiencies, metabolic disorders, and inadequate dietary diversity during pregnancy may elevate the risk of Autism Spectrum Disorder (ASD) in offspring (Lyall et al., 2017). Genetics is still a big factor, but changing what you eat can help prevent problems, especially in countries like Bangladesh, where malnutrition is still a big public health problem.

The remainder of this section presents global evidence on maternal nutrition and autism risk, studies the relevant biochemical pathways, and interprets the findings in the context of the Bangladeshi population.

Diet-Linked Patterns of Autism

Some autism cases have been related to nutrient deficiencies during pregnancy, which impact brain development in multiple ways:

Nutrient Deficiency	Possible Autism-Related Patterns	Reference for patterns
Folate (Vitamin B9)	Social communication difficulties, speech delay, and cognitive impairment	(Rai et al., 2018)
Vitamin D	Sensory processing problems, emotional dysregulation, and attention difficulties	(Fernell et al., 2015)
Omega-3 fatty acids (DHA)	Poor memory, slow learning, and language processing problems	(Bent et al., 2014)
Iron	Behavioral problems, hyperactivity, reduced cognitive performance, and emotional instability	(Krebs et al., 2000)
Iodine	Intellectual disability, delayed developmental milestones, and speech delay	(Zimmermann, 2011)

Table 01: Role of Key Micronutrient Deficiencies in Autism-Linked Developmental Patterns

Lifestyle-Linked Autism Influences Maternal lifestyle during pregnancy can affect the neurodevelopmental pathways**,** contributing to different autism-related characteristics.

Maternal Lifestyle Factor	Associated Autism Traits (Research-Based)	Reference for associated traits
High stress or anxiety during pregnancy	Social withdrawal, emotional dysregulation, anxiety-related behaviors, and attention difficulties	(Catalano et al., 2021)
Poor sleep during pregnancy	Attention problems, sensory sensitivity, irritability, and increased risk of autism-related traits	(Hirota et al., 2022a)
Physical inactivity during pregnancy	Cognitive delay, poorer language development, and motor coordination difficulties	(Hirota et al., 2022b)
Maternal obesity or gestational diabetes	More severe autism symptoms, repetitive behaviors, and neurodevelopmental impairment	(Li et al., 2023)
Exposure to tobacco smoke or second-hand smoke	Language delay, aggressive behavior, hyperactivity, and elevated autism-related trait scores	(Ritz et al., 2022)

Table 02: Maternal Lifestyle Factors Linked to Autism Traits

Folate and Neural Tube Development

The mineral folic acid, or vitamin B9, is a key micronutrient that is needed for many biochemical processes that are important for early fetal development, such as DNA synthesis, cell division, neurogenesis, and methylation. It is very important during the periconceptional and early gestation periods, when fetal cells grow quickly, especially in the developing neural tube, which later becomes the brain and spinal cord (DeVilbiss et al., 2015). Folate is involved in one-carbon metabolism, which is important for regulating DNA methylation and epigenetics. A lack of folate can mess up these processes, which can hurt neuronal differentiation, synaptic formation, and cognitive development. All of these are important for neurodevelopmental outcomes, such as the possible development of Autism Spectrum Disorder (ASD) (Schmidt et al., 2019). Numerous population-based studies have demonstrated that maternal folic acid supplementation before conception and during the initial trimester markedly decreases the risk of neural tube defects and enhances cognitive outcomes in offspring. (Surén et al.,2013) found that giving mothers folic acid supplements before conception and during the first trimester can lower the risk of ASD by about 40%, especially in children who are genetically more likely to get it. This protective effect has been associated with folate's capacity to modulate gene expression, sustain neuronal cell proliferation, and promote optimal brain structure and function. Insufficient folate levels during gestation can interfere with DNA methylation, resulting in atypical gene expression within neural tissue (Schmidt et al., 2019). These epigenetic modifications may influence the maturation of brain regions, including the prefrontal cortex and hippocampus, which are integral to social communication, memory, and emotional regulation—domains frequently impacted in individuals with ASD. An inadequate supply of folate during pregnancy can also cause the folate receptor alpha (FRα) to work incorrectly. This receptor is very important for moving folate across the placenta and into the developing fetal brain. When a mother doesn't have enough folate, folate receptor autoantibodies can form, which can stop folate from getting to the fetal central nervous system. This disruption may lead to compromised neurodevelopmental and behavioral outcomes, encompassing ASD-like characteristics (Schmidt et al., 2019). These biological mechanisms substantiate the hypothesis that maternal folate deficiency is not solely a nutritional issue but may also serve as an epigenetic and metabolic factor affecting autism risk in offspring.

The effects of a lack of folate in pregnant women are especially important in low- and middle-income countries like Bangladesh, where many pregnant women don't get enough nutrients. A lot of pregnant women in Bangladesh eat a lot of rice, but they don't eat many leafy green vegetables, legumes, nuts, eggs, or fortified foods, which are the main sources of dietary folate (NIPORT, 2020). Cultural dietary restrictions, food insecurity, inadequate awareness of nutritional requirements during pregnancy, and restricted access to prenatal supplements substantially impact the low folate intake among pregnant women. A high rate of anemia and inadequate micronutrient intake also worsen the risk of deficiency. Many pregnant women in Bangladesh also don't start taking supplements containing folic acid before they get pregnant, which is very important for preventing neural tube defects and helping the brain grow early (NIPORT, 2020). Bangladesh also has problems with antenatal care as a whole, since many women don't get enough nutritional counseling or supplements in the early stages of pregnancy.

Cultural norms and social pressures may prevent women from eating some healthy foods, making it even harder for them to get enough folate from green vegetables or animal proteins. Additionally, the high rate of anemia in Bangladeshi women is often linked to low levels of folate, iron, and vitamin B12 at the same time. This creates a wider range of nutritional deficiencies, which could increase the risk of developmental disorders (NIPORT, 2020). Low levels of education and poor access to maternal healthcare make it even harder for people to learn about prenatal nutrition needs and follow supplementation programs. These issues create a situation in which a significant number of pregnancies in Bangladesh occur in nutritionally precarious conditions, potentially heightening the risk of neurodevelopmental impairments in offspring. From a public health perspective, enhancing prenatal folate supplementation and increasing maternal dietary diversity could be cost-effective, high-impact strategies to improve neurodevelopmental outcomes. Research from various international studies, including Surén et al. (2013), underscores that early folate supplementation is particularly essential before conception and in the early phases of pregnancy, for neuroprotection. Antenatal clinics, community health outreach, and NGO-led maternal nutrition efforts are all national maternal health programs in Bangladesh that can help pregnant women learn about folic acid supplementation and nutrition. But implementation is still not the same in all areas, especially in rural and low-income urban areas.

In summary, folate is a vital micronutrient necessary for healthy fetal brain development, and its deficiency is associated with neurodevelopmental disorders, including ASD. Global studies have shown that taking folic acid supplements during pregnancy can help protect against certain problems. However, Bangladesh has its own problems, such as a lack of variety in the diet, not enough supplements being used, anemia, and not enough prenatal care, all of which make it more likely that mothers will not get enough folate. Based on current evidence, enhancing maternal folate intake may substantially mitigate ASD vulnerability; however, additional research specific to Bangladesh is required to validate the magnitude of this correlation.

Vitamin D and Neuroendocrine Function

Vitamin D is an important nutrient during pregnancy because it is important for neurological development, immune modulation, and neuroprotective signaling. Vitamin D has a big effect on neuronal differentiation, synaptic formation, neurotransmitter production, and cortical connectivity, which are all important for fetal brain development (Vinkhuyzen et al., 2018). Other vitamins mostly help with physical growth. Vitamin D receptors are prevalent in brain regions that govern interactions with others, memory, language, emotional regulation, and sensory processing. These areas are the prefrontal cortex, hippocampus, amygdala, and cerebellum. People with Autism Spectrum Disorder (ASD) have been shown to have structural and functional differences in these areas. Consequently, prenatal vitamin D deficiency may disrupt essential neurodevelopmental processes, modifying pathways that influence the etiology of ASD.

One of the major forms in which vitamin D affects brain development is by controlling calcium signaling in the brain. Calcium plays a role in neurotransmission, neuronal migration, and synaptic activity. In the developing brain, calcium regulates neuronal firing and facilitates the establishment of excitatory and inhibitory equilibrium. Low maternal vitamin D disrupts calcium signaling pathways, potentially impacting on neuronal communication and synaptic maturation, resulting in structural abnormalities associated with ASD (Mazahery et al., 2019). Vitamin D also helps GABAergic signaling, which is the brain's main inhibitory neurotransmitter system. Problems with GABA (gamma-aminobutyric acid) activity have been scientifically linked to symptoms of ASD, such as being overly sensitive to sensory input, repeating behaviors, and having trouble communicating with others. Lower levels of vitamin D during pregnancy may harm GABAergic pathways, which could affect neurobehavioral outcomes later in childhood (Mazahery et al., 2019).

Vitamin D also plays an important role in how the immune system works and how the body responds to inflammation. Maternal immune activation can change how the fetal brain develops during pregnancy. Vitamin D helps keep the immune system in balance by lowering levels of inflammatory cytokines, especially interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and interleukin-1β. These inflammatory markers are associated with abnormal brain connectivity and the pathophysiology of ASD (Mazahery et al., 2019). Low maternal vitamin D levels correlate with increased concentrations of inflammatory cytokines, potentially hindering neurodevelopment during crucial phases of fetal brain development. Vitamin D influences structural brain development and serves as a neuroprotective function by mitigating inflammation-induced neural damage.

Studies on epidemiology substantiate the association between prenatal vitamin D deficiency and the risk of autism spectrum disorder (ASD). Vinkhuyzen et al. (2018) examined neonatal blood samples and discovered that reduced neonatal serum vitamin D levels were significantly correlated with an increased probability of ASD traits in childhood. The research indicated that vitamin D levels during pregnancy and early neonatal life directly affect developmental outcomes associated with ASD. Additionally, the authors posited that vitamin D deficiency does not singularly induce autism but rather heightens developmental susceptibility in genetically predisposed contexts. This corresponds with the increasing consensus that ASD arises from gene-environment interactions, wherein environmental factors, such as nutritional deficiencies, exacerbate genetic susceptibility.

Vitamin D deficiency is very common in Bangladesh, even though the country gets a lot of sunlight all year round. The deficiency issue arises not from insufficient sunlight but from behavioral, environmental, and cultural obstacles that diminish UV-B exposure. Urbanization, indoor living, air pollution, and cultural dress codes make it harder for women to get enough sunlight, especially when they are pregnant (Islam et al., 2021). In Bangladesh, pregnant women often stay inside most of the time because of social norms, safety concerns, and household duties. In cities like Dhaka, Chattogram, and Gazipur, heavy pollution blocks UV-B rays, which stops the body from making enough vitamin D from the skin. Islam et al. (2021) also said that traditional clothing worn by women, especially in conservative societies, covers a lot of their bodies, which makes it even harder for them to get sun exposure. Because of this, vitamin D deficiency is still common among pregnant women in Bangladesh, even in sunny places.

Bangladesh has very little vitamin D in its diet and very little sunlight exposure. Many people don't eat enough foods that are high in vitamin D, like oily fish, egg yolks, liver, and fortified dairy products. Unlike in many Western countries, the maternal healthcare system in Bangladesh does not often give pregnant women vitamin D supplements. These factors contribute to a "hidden epidemic" of hypovitaminosis D that jeopardizes pregnant women and their unborn children, leading to neurodevelopmental impairments, including vulnerabilities associated with ASD.

These findings underscore that maternal vitamin D status is a modifiable risk factor for ASD, especially in areas such as Bangladesh, where deficiency is prevalent. To lower the neurodevelopmental risks linked to vitamin D deficiency, it might be helpful to make sure people get enough sunlight, encourage vitamin D supplements, and make policies that add vitamin D to food. While additional Bangladesh-specific research is necessary to validate direct associations with ASD, global and theoretical evidence robustly underscores the vital role of vitamin D in fetal brain development and the risk of autism.

Omega-3 Fatty Acids (DHA), Maternal Health, and ASD Risk

Omega-3 long-chain polyunsaturated fatty acids (LC-PUFAs), especially docosahexaenoic acid (DHA), are very important for the development of the fetal brain. DHA is a part of the structure of neuronal cell membranes and helps with neuronal signaling, synaptic plasticity, and myelination, which are all important for proper neural transmission and cognitive processing (Coletta et al., 2010). DHA is especially high in the cerebral cortex and retina, which is why it is so important during the third trimester of pregnancy when the fetal brain and visual system are growing quickly. Thus, sufficient maternal DHA levels are crucial for optimal neurodevelopmental results.

A deficiency of DHA in mothers during pregnancy has been associated with hindered fetal cortical development, atypical myelin synthesis, and disrupted neural connectivity. Research indicates that inadequate DHA levels during gestation may lead to diminished brain volume, compromised memory function, and delayed language development in infants (Weiser et al., 2016). Also, a deficiency in DHA has been linked to heightened risks of neurodevelopmental disorders, including Autism Spectrum Disorder (ASD). Although autism is not directly caused by nutritional deficiency, prenatal DHA levels may affect the risk of ASD by changing how the brain develops, how synapses signal, and how the body responds to inflammation (Weiser et al., 2016).

Inflammation is one of the main ways that DHA and ASD risk are linked. Omega-3 fatty acids possess anti-inflammatory characteristics, aiding in the regulation of immune responses during gestation. When maternal DHA levels are insufficient, pro-inflammatory cytokines like IL-6 and TNF-alpha tend to rise, possibly traversing the placenta and impacting fetal brain development (Yui et al., 2016). This neuroinflammatory environment can change how neurons send signals and how new neurons are made, which can make people more likely to get ASD and other neurodevelopmental disorders. Additionally, not having enough DHA can change how fluid the cell membrane is, which can make it harder for neurotransmitters to bind and receptors to work properly. This disruption can hinder synaptic communication, potentially leading to neurodevelopmental abnormalities linked to ASD (Yui et al., 2016).

Children with ASD suffer from altered DHA metabolism, as multiple studies indicate reduced DHA levels in the plasma and red blood cells of autistic children relative to their typically developing counterparts (Yui et al., 2016). This indicates that insufficient DHA during fetal development may impact early brain growth and yield enduring effects throughout childhood. DHA is important for the growth of the prefrontal cortex, which is the part of the brain that controls social behavior, decision-making, and communication. These are all areas that individuals with ASD often have trouble with.

In Bangladesh, not getting enough omega-3 is a special problem. People all over the country eat fish, but the amount of DHA they get from it varies a lot depending on where they live, how much money they have, and how easy it is for them to get good fish. A lot of people who live in cities eat more farmed fish than fish caught in the wild. Because of differences in feed quality, farmed fish tend to have lower DHA levels, which makes it hard to get enough omega-3s. Also, a lot of low-income families eat a lot of rice and not enough foods that are high in omega-3s, like fish, eggs, and nuts. Cultural dietary preferences, food insecurity, and lack of awareness make the problem even worse.

View of Bangladeshi pregnant women is not often screened for omega-3 deficiency, and DHA is not always included in prenatal supplementation programs. Iron, folate, and calcium are the main nutrients that maternal nutrition programs look at. DHA and other important fatty acids don't get as much attention. This indicates a possible public health deficiency, as omega-3 supplementation during gestation could facilitate fetal brain development and probably mitigate neurodevelopmental risks.

Omega-3 fatty acids, and especially DHA, are necessary for the development of the fetal brain because they affect neuronal structure, synaptic connectivity, neurotransmitter function, and the control of inflammation. A lack of DHA in mothers has been linked to problems with cognitive development and a higher risk of ASD, especially through inflammation and problems with synaptic communication (Coletta et al., 2010; Weiser et al., 2016; Yui et al., 2016). In Bangladesh, even though many people eat fish, they don't always get enough DHA because of dietary restrictions, low income, and a lack of nutritional knowledge. Enhancing maternal DHA consumption via dietary recommendations or prenatal supplementation may serve as an effective approach to promote neural development and health and potentially mitigate risks associated with ASD.

Iron and Anemia

Iron is essential for oxygen, e.g., transport, myelination, and neurotransmitter synthesis, all of which are critical for fetal brain development. Maternal iron deficiency anemia can impair dopaminergic and serotonergic pathways, which are linked to behavioral and cognitive functions in autism (Mahaffey et al., 2017). Insufficient iron during pregnancy is associated with cognitive delays, behavioral disorders, and increased ASD susceptibility. In Bangladesh, anemia remains highly prevalent, affecting around 40% of pregnant women, highlighting a significant public health concern with potential long-term neurodevelopmental impacts (NIPORT, 2020). Iron is an essential micronutrient that plays a critical role in multiple aspects of fetal brain development, including oxygen transport, neuronal myelination, neurotransmitter synthesis, and cognitive functioning. During pregnancy, iron demands significantly increase because the mother must support the rapid development of fetal tissues, placenta formation, and expanded maternal blood volume. When dietary intake and absorption of iron are inadequate, pregnant women can develop iron deficiency anemia, which reduces the body's ability to deliver oxygen to the developing fetus and may impair neurological development (Mahaffey et al., 2017). Iron supports brain growth through its role in myelination, a process that insulates nerve fibers to enhance electrical signal transmission between neurons. Disruption of this process can weaken neural connectivity, affecting sensory processing, cognition, and behavior—factors commonly associated with Autism Spectrum Disorder (ASD).

Another core role of iron is in neurotransmitter synthesis. Iron functions as a cofactor in the production of neurotransmitters, including dopamine and serotonin, both of which are involved in emotional regulation, mood stability, reward processing, attention, and social behavior. Deficiency of iron during pregnancy may impair the development of dopaminergic and serotonergic pathways, potentially leading to behavioral disorders, social communication challenges, and emotional dysregulation, which are key features of ASD. Research suggests that insufficient iron levels during key periods of fetal brain development may disrupt these neurotransmitter systems, increasing the risk of ASD-related behaviors in later childhood (Mahaffey et al., 2017). Additionally, iron helps regulate brain energy metabolism through its role in mitochondrial function, contributing to neuronal survival, differentiation, and synaptic signaling. When iron deficiency occurs during pregnancy, these processes may be compromised, affecting brain structure and function in ways that could increase the vulnerability to ASD.

Iron deficiency anemia has also been linked to cognitive delays, behavioral disorders, and impaired language development in children. Anemic mothers are more likely to give birth to infants with low birth weight and lower Apgar scores—markers that have been associated with developmental delays and neurobehavioral disorders. Mahaffey et al. (2017) reported that children born to mothers with untreated iron deficiency anemia were more likely to exhibit delayed motor skills, attention deficits, learning challenges, and behavioral abnormalities. In some cases, maternal anemia was associated with emotional reactivity, poor memory formation, and communication challenges, all of which reflect early indicators of ASD-like traits. Iron deficiency can lead to slower nerve conduction, reduced brain cell proliferation, and altered white matter integrity, which may affect neural circuits associated with social interaction and sensory integration.

In Bangladesh, maternal anemia remains a significant public health concern. According to national health surveys, anemia affects approximately 40% of Bangladeshi women of reproductive age, and a considerable proportion of them experience iron deficiency during pregnancy (NIPORT, 2020). Many women enter pregnancy already malnourished, and their diets often lack iron-rich foods such as meat, fish, legumes, or fortified foods. Cultural practices, poverty, limited antenatal care, and lack of awareness further contribute to persistent maternal anemia across both rural and urban areas. In many parts of Bangladesh, pregnant women consume diets heavily centered on rice and low in bioavailable iron, and practices such as drinking tea with meals reduce iron absorption. Furthermore, reasons such as early pregnancies, repeated childbirth, menstruation-related blood loss, and parasitic infections exacerbate iron deficiency in women and girls. This nutritional burden not only threatens maternal health but also poses risks to fetal brain development and neurodevelopmental outcomes nationwide.

While ASD is a complex condition influenced by multiple genetic, nutritional, environmental, and biological factors, maternal iron deficiency may be one of the modifiable risk factors that contribute to ASD vulnerability. The neurological implications of anemia during pregnancy highlight the importance of timely detection and treatment. Public health interventions in Bangladesh often focus on providing iron and folic acid supplements to pregnant women through antenatal care programs. However, coverage and adherence remain limited, especially in remote and underserved areas. Many women are unaware of the importance of iron supplementation or discontinue supplementation due to gastrointestinal side effects, lack of counseling, or cultural misconceptions. Addressing these challenges requires nutrition education, community awareness, and stronger implementation of maternal health services.

Supporting maternal health and preventing iron deficiency during pregnancy may help reduce the risk of impaired neurodevelopmental outcomes in children, including ASD-related behaviors. While more Bangladesh-specific research is needed to examine the direct relationship between maternal iron deficiency and ASD, existing evidence highlights strong biological and neurological pathways through which iron deficiency could potentially contribute to autism risk. Given the high prevalence of anemia in Bangladeshi women and its potential consequences on fetal brain development, addressing iron deficiency should be considered a public health priority. Encouraging balanced diets rich in iron, promoting prenatal supplementation, and improving maternal healthcare access could help reduce neurodevelopmental vulnerabilities and improve cognitive outcomes in future generations of Bangladeshi children.

2.2 Dietary Patterns in Bangladesh

Bangladesh's dietary structure is heavily influenced by economic, cultural, and environmental factors. Pregnant women usually consume diets dominated by rice, limited protein, and insufficient fruits and vegetables (Ahmed et al., 2020).

Aspect	Rural Pregnant Women (Bangladesh)	Urban Pregnant Women (Bangladesh)
Staple food intake (rice, lentils)	Diet predominantly based on rice and lentils with very low dietary diversity (Ahmed et al., 2020; Rahman et al., 2018).	High rice consumption with relatively greater dietary diversity, including vegetables and animal-source foods (FAO & FANTA, 2016; BDHS, 2020).
Animal protein (fish, meat, eggs)	Irregular and low intake due to affordability and limited availability (Rahman et al., 2018; Ahmed et al., 2020).	Higher and more frequent intake of fish, meat, eggs, and poultry, particularly among middle- and high-income households (Alam et al., 2021).
Fruits and vegetables	Limited fruit consumption due to seasonal availability; moderate vegetable intake (FAO & FANTA, 2016).	Higher intake of fruits and vegetables with better year-round access (Alam et al., 2021; BDHS, 2020).
Milk and dairy products	Very low consumption, often less than one glass per day (Ahmed et al., 2020).	Higher consumption due to improved market access and affordability (Rahman et al., 2018).
Micronutrient supplementation (iron–folate, calcium)	Irregular or absent use due to inadequate antenatal care coverage and limited awareness (BDHS, 2020; UNICEF Bangladesh, 2019).	More regular use of iron–folate, calcium, and multivitamin supplements through private clinics and NGO-supported services (WHO, 2016; BDHS, 2020).
Junk / fast food consumption	Very low or occasional consumption (Islam et al., 2020).	High and frequent intake of fast foods, fried snacks, and sugar-sweetened beverages (Islam et al., 2020).
Second-hand smoke exposure	High exposure due to indoor smoking by household members and community environments such as tea stalls (BDHS, 2020; WHO, 2018).	High exposure from homes, workplaces, and public spaces despite existing tobacco control regulations (BDHS, 2020).
Indoor air pollution	Very high exposure from biomass fuel use (firewood, cow dung, kerosene stoves) for cooking (WHO, 2018; Smith et al., 2014).	Lower biomass fuel use, but exposure persists from gas leakage, incense burning, mosquito coils, and indoor smoke (Begum & Hopke, 2019).

Outdoor air pollution	Moderate exposure due to lower traffic density, though seasonal dust contributes to pollution (Begum & Hopke, 2019).	Very high exposure from traffic emissions, brick kilns, construction activities, and industrial pollution (WHO, 2021; Begum & Hopke, 2019).
Psychosocial stress	Stress primarily related to poverty, food insecurity, and heavy physical workload (Nasreen et al., 2011).	Stress associated with urban crowding, employment pressure, traffic congestion, and social demands (Rahman et al., 2013).
Overall autism-related maternal risk profile (conceptual)	Higher risk linked to nutritional deficiencies, anemia, and indoor air pollution, along with limited access to early diagnosis and intervention services (Lyall et al., 2017; Modabbernia et al., 2017).	Higher risk associated with environmental pollution, psychosocial stress, chemical exposure, and advanced parental age, alongside better access to diagnostic services (Lyall et al., 2017).

Table 03: Comparison of food habits and autism-related maternal risk factors among urban and rural pregnant women in Bangladesh

Common Dietary Challenges:

Expectant Bangladeshi women frequently encounter various nutritional obstacles that have a detrimental impact on the development of the fetus's nervous system. Many women consume less than five food groups daily, which leads to a limited intake of vital micronutrients and is a widespread phenomenon due to the low diversity of their diets. The development of the brains of both the mother and the fetus is further jeopardized by the presence of heavy metals in foods that are commonly consumed, such as arsenic in rice, lead in vegetables, and mercury in fish (Rahman et al., 2021). The consumption of diets that are rich in carbs and low in protein may be a contributing factor to the development of gestational diabetes, which is linked with the elevated risk of autism spectrum disorder (Xu et al., 2014). Furthermore, despite the recommendations of healthcare professionals, the usage of prenatal vitamin supplements continues to be low, and food insecurity continues to be a barrier to obtaining nutritional foods, especially in homes with low incomes. As a result of these combined causes, there is a worsening of the deficits in micronutrients, and the risk of neurodevelopmental consequences that link to autism in Bangladesh may be greatly increased.

2.3 Global vs. Local Nutritional Risk Factors

Research worldwide has pinpointed many maternal dietary risk factors associated with Autism Spectrum Disorder (ASD). Folate insufficiency is linked to disrupted DNA methylation and neural tube development, heightening susceptibility to Autism Spectrum Disorder (Schmidt et al., 2019). Vitamin D insufficiency negatively impacts neurodevelopmental processes, immunological modulation, and neural communication, hence leading to autism-related characteristics (Vinkhuyzen et al., 2018). Maternal obesity and high-fat diets may induce systemic inflammation and insulin resistance, so impairing fetal brain development and elevating the risk of Autism Spectrum Disorder (Krakowiak et al., 2012). Gestational diabetes has also been associated with oxidative stress, inflammatory imbalance, and modified metabolic programming, affecting neurodevelopmental outcomes (Xu et al., 2014). Insufficient omega-3 fatty acid consumption during pregnancy disrupts neuronal membrane development, synaptic plasticity, and neurotransmitter activity, all essential for cognitive and behavioral maturation (Yui et al., 2016). These risk factors affect ASD. Bangladesh has several special problems that make youngsters more likely to get ASD. High rates of maternal anemia, chronic malnutrition, and limited access to prenatal vitamin supplementation impede optimal fetal brain development. Food contamination is a big problem because pesticides, lead, arsenic, mercury, and other industrial contaminants are often found in vegetables, seafood, and rice grown in the area. Rapid industrialization and urbanization have made food and water quality even worse and made people more likely to come into contact with neurotoxic compounds. Socioeconomic limitations also restrict access to healthful foods, prenatal healthcare, and nutritional supplements, especially in rural and low-income areas. These local factors interact with biological pathways described in global studies, underscoring that ASD risk in Bangladesh is affected not only by nutrition and metabolism but also by environmental toxicity.
So, while research from around the world points to biological and dietary factors that increase the risk of ASD, the situation in Bangladesh shows that undernutrition, poverty, a dirty food supply, and environmental risks make people even more vulnerable. To make prevention methods that work in many cultures and settings, it's important to know both global and local risk factors. Such insights can assist policymakers, healthcare practitioners, and public health researchers in formulating maternal nutrition programs, food safety legislation, and prenatal therapies that are particular to the Bangladeshi environment. Inflammatory pathways, problems with mitochondria, and epigenetic control.

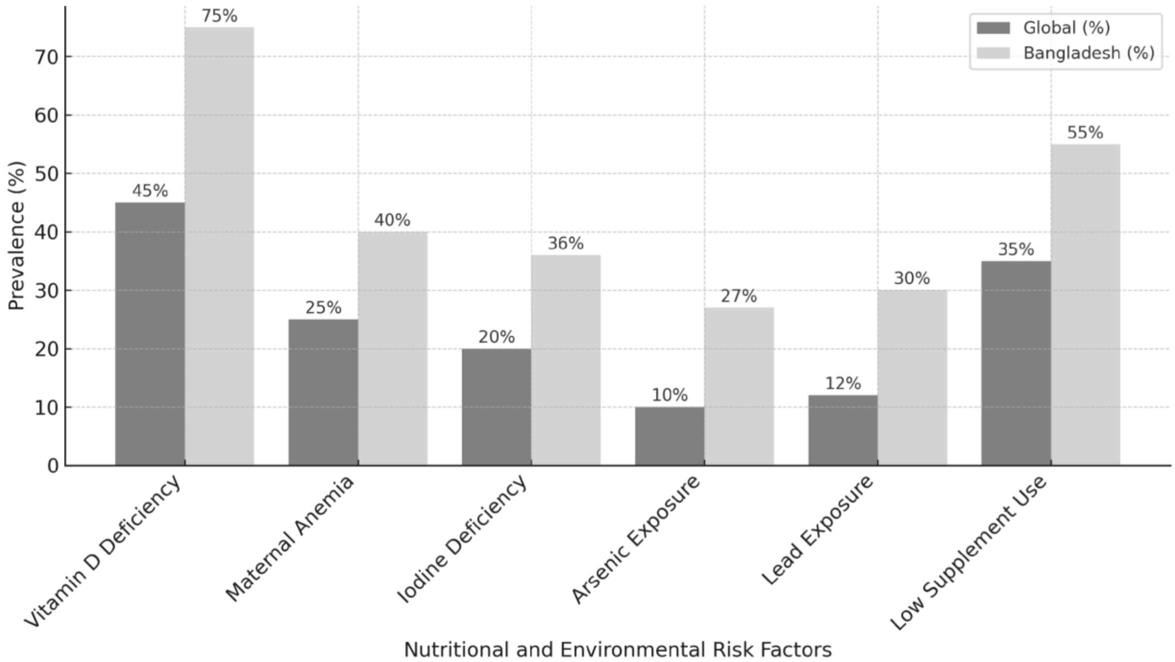

Figure 03: Comparison of global and Bangladesh-specific maternal nutritional and environmental risk factors associated with Autism Spectrum Disorder (ASD).

Figure 3 shows that maternal nutritional deficiencies and environmental exposures associated with ASD are substantially higher in Bangladesh than global averages. Higher rates of vitamin D deficiency, anemia, iodine insufficiency, and inadequate prenatal supplement adherence have been reported among Bangladeshi mothers (Islam et al., 2022; NIPORT, 2020). In addition, exposure to arsenic-contaminated groundwater and lead in food products poses further risks to fetal neurodevelopment (Rahman et al., 2017; Jahan & Hossain, 2020). These findings are consistent with evidence that metabolic and nutritional disturbances during pregnancy increase ASD susceptibility through immune and neuroinflammatory mechanisms (Xu et al., 2014).

Chapter 3: Lifestyle Factors During Pregnancy

3.1 Stress, Sleep, and Mental Health

The lifestyle of a mother during pregnancy is very important for the development of the fetus and the health of the baby after birth. In addition to genetics and nutrition, lifestyle factors such as stress levels, sleep quality, physical activity, and substance exposure can profoundly affect fetal brain development and may increase the risk of Autism Spectrum Disorder (ASD) (Beversdorf et al., 2018). These influences interact via biological mechanisms including inflammation, oxidative stress, hormonal dysregulation, and compromised neuronal connectivity (Modabbernia et al., 2017). Although global studies have thoroughly examined these associations, there is a paucity of research in South Asian contexts, especially

Bangladesh, where socioeconomic stressors, environmental pressures, and cultural constraints engender distinctive maternal lifestyle patterns. This chapter examines the primary lifestyle-related factors during pregnancy and their possible associations with autism risk, substantiated by global evidence and contextualized within the Bangladeshi population.

Maternal Stress

Stress in Mothers maternal psychological stress is a prevalent focus of research regarding prenatal risk factors for ASD. Chronic stress exposure during pregnancy elevates maternal cortisol levels, which can traverse the placenta and affect fetal brain development (Kaplan et al., 2019). Elevated cortisol levels may interfere with neurogenesis, modify synaptic pruning, and disrupt the hypothalamic–pituitary–adrenal (HPA) axis—mechanisms associated with autism (Kinney et al., 2008). Numerous studies indicate that mothers subjected to significant stressors, including natural disasters, warfare, trauma, or economic difficulties, exhibit an elevated probability of delivering children subsequently diagnosed with Autism Spectrum Disorder (Li et al., 2009). Stress-induced inflammation further elevates pro-inflammatory cytokines, such as IL-6, which affect the formation of fetal neural circuits (Gumusoglu & Stevens, 2019).

Pregnant women in Bangladesh often face multiple psychosocial and environmental challenges, such as financial strain, heavy household responsibilities, urban overcrowding, occupational burdens in the garment and informal sectors, and limited access to mental health care. These persistent stressors can elevate prenatal stress levels, triggering hormonal, inflammatory, and oxidative changes that may adversely influence fetal neurodevelopment. Sleep disturbance is one of the most common problems during pregnancy due to hormonal, physical, and emotional changes. Inadequate maternal sleep has been linked to impaired fetal growth, increased inflammatory biomarkers, altered immune responses, and disrupted maternal metabolism, which may contribute to neurodevelopmental vulnerabilities (Facco et al., 2018; Okun et al., 2019). Although direct associations between maternal sleep quality and Autism Spectrum Disorder (ASD) are still being investigated, researchers emphasize that poor sleep may be a modifiable risk factor influencing cognitive and behavioral development.

Sleep Quality

In Bangladesh, sleep disruptions among pregnant women are further intensified by environmental noise, overcrowded living spaces, mosquito infestations, heat stress, unsafe housing conditions, and insufficient healthcare guidance on sleep hygiene, highlighting the need for improved prenatal care and supportive maternal health services.

Depression and Anxiety

Prenatal depression and anxiety affect fetal brain development via chronic inflammation, oxidative stress, and hormonal imbalance (Liu et al., 2016). Maternal depression correlates with modified fetal stress regulation, diminished cortical development, and subsequent neurobehavioral difficulties. Numerous population-based studies indicate an increased risk of ASD in children born to mothers exhibiting untreated prenatal anxiety or depressive symptoms (Raz et al., 2015).

In Bangladesh, the prevalence of depression among pregnant women is markedly elevated compared to global estimates, attributable to poverty, domestic stress, and restricted access to psychiatric care (Nasreen et al., 2011). These vulnerabilities underscore the necessity for prenatal mental health interventions.

3.2 Physical Activity and Metabolic Conditions

Maternal lifestyle factors like obesity, physical activity, and gestational diabetes have a big impact on fetal brain development and the risk of developmental disorders like Autism Spectrum Disorder (ASD). Regular physical activity by mothers helps the placenta work better, deliver more oxygen and nutrients, lower inflammation, and better control metabolism (Downs et al., 2019). These physiological advantages create a milieu that promotes healthy neurogenesis, myelination, and synaptic connectivity in the developing fetal brain. Research shows that moderate exercise during pregnancy is good for brain development and lowers the risk of developmental problems (Clapp, 2008). Conversely, physical inactivity heightens the risk of negative pregnancy outcomes, including gestational diabetes, excessive maternal weight gain, hypertension, and chronic inflammatory states, all of which may interfere with neurodevelopmental pathways and increase the risk of ASD. In Bangladesh, the physical activity levels of pregnant women vary greatly depending on where they live, with big differences between people who live in cities and those who live in rural areas. Urban pregnant women, especially those in Dhaka and Chattogram, frequently exhibit low levels of physical activity due to various socioeconomic and cultural barriers, such as limited mobility, absence of safe public spaces, sedentary employment in the garment or office sectors, societal discouragement of exercise during pregnancy, and insufficient awareness of the advantages of prenatal physical activity. On the other hand, many pregnant women in rural areas do hard physical work like farming, carrying water, and doing chores around the house. This can make them tired, stressed, and strain their muscles and joints. This shows that both too little and too much physical activity can be bad for the health of the mother and the baby. In addition to physical activity, maternal obesity and gestational diabetes mellitus (GDM) have been recognized as significant risk factors for autism spectrum disorder (ASD). Research has identified correlations through mechanisms including chronic low-grade inflammation, insulin resistance, oxidative stress, fetal hypoxia, and metabolic dysregulation (Krakowiak et al., 2012). These conditions are recognized to adversely affect neurodevelopment by impairing neural cell differentiation, synaptic formation, and cerebral connectivity (Xu et al., 2014). Maternal hyperglycemia changes the metabolic environment inside the womb, which affects insulin and cytokine signaling. This could lead to epigenetic changes in the fetal brain that are linked to ASD. In Bangladesh, obesity and gestational diabetes were not common in the past. However, rapid urbanization, diets that are high in calories but low in nutrients, early maternal age, and a lack of nutritional counseling have all led to more mothers being overweight and having gestational diabetes. Many Bangladeshi women eat a lot of rice, don't get enough protein, and don't get enough micronutrients. This makes it harder for their bodies to stay in balance and raises their risk of insulin resistance and inflammatory problems during pregnancy. Inadequate antenatal care, delayed diagnosis of gestational diabetes mellitus (GDM), cultural stigma surrounding weight gain, and limited awareness of metabolic health exacerbate pregnancy-related risks. A combination of lifestyle factors, such as not getting enough or too much exercise, being overweight during pregnancy, and having gestational diabetes, interacts with nutritional and psychosocial factors to make a complicated risk profile that could affect fetal brain development and the risk of autism spectrum disorder (ASD). To deal with these problems, we need awareness campaigns, culturally appropriate antenatal exercise programs, better screening for GDM, and dietary advice that is specific to the Bangladeshi context. Bangladesh can lower the developmental risks that come with being inactive, overweight, or having gestational diabetes by encouraging a healthy lifestyle and metabolic health during pregnancy. This will lead to healthier neurodevelopmental outcomes for future generations.

3.3 Substance Exposure

Tobacco Smoke

Active smoking during pregnancy is linked to impaired fetal oxygen supply, inflammation, and abnormal brain development. Even more concerning in the perspective of Bangladesh is second-hand smoking**,** which exposes non-smokers to high levels of nicotine and carbon monoxide. In the past, studies have shown that children exposed to prenatal tobacco smoke have a higher likelihood of ASD-related traits, behavioral problems, and cognitive impairments (Tran et al., 2020). In Bangladesh, 95% of households are exposed to second-hand smoke due to widespread male smoking habits, placing many pregnant women at consistent risk.

Figure 04: Multifactorial Influences of Mother on Autism Spectrum Disorder: Diet, Lifestyle, and Environment

Indoor Air Pollution from Cooking Fuel

Indoor air pollution resulting from the use of traditional cooking fuels poses a substantial risk to maternal and fetal health in Bangladesh, particularly among low-income rural and peri-urban households that rely heavily on biomass fuels such as wood, cow dung, charcoal, and crop residues (Khan et al., 2017). These fuels release elevated levels of toxic pollutants, including carbon monoxide and fine particulate matter (PM2.5), which are associated with adverse pregnancy outcomes such as low birth weight and preterm delivery (Khan et al., 2017). Pregnant women experience higher exposure due to prolonged time spent near cooking stoves, increasing health risks to both mother and fetus. Local studies indicate that women who use solid fuels for cooking experience markedly elevated PM2.5 exposure, frequently exceeding WHO safety thresholds by 20–30 times (Khan et al., 2017; World Health Organization [WHO], 2014).

Long-term exposure to air pollutants during gestation may trigger maternal immune activation, leading to inflammatory responses that interfere with fetal neurodevelopment and increase susceptibility to autism spectrum disorder (Yu et al., 2023; Wang et al., 2021). In Bangladesh, poor ventilation and reliance on traditional stoves exacerbate indoor pollution exposure, with PM2.5 levels often far exceeding WHO-recommended limits. Promoting clean cooking technologies and improved ventilation remains essential for reducing these health risks.

Alcohol, Drug, and Medication Use During Pregnancy

Alcohol and recreational drug use during pregnancy are globally recognized for their harmful impact on fetal brain development. Although alcohol consumption is relatively uncommon among pregnant women in Bangladesh due to cultural, social, and religious norms, its teratogenic potential makes it an important risk factor in global ASD research. Prenatal alcohol exposure interferes with neuronal migration, axonal growth, synaptic development, and neurotransmitter functioning, a key process involved in early brain formation (Mattson et al., 2019). Alcohol crosses the placental barrier, leading to oxidative stress, neural apoptosis, and alteration of critical brain regions such as the hippocampus and prefrontal cortex, which are deeply associated with memory, emotional regulation, and social behavior, areas commonly affected in Autism Spectrum Disorder (ASD). Children prenatally exposed to alcohol may exhibit a range of developmental challenges, including attention deficits, learning disability, and behavioral impairment, with some traits overlapping with autism-related symptoms such as poor eye contact, delayed communication, and social withdrawal (Mattson et al., 2019).

While recreational drug use is also rare in Bangladesh, occasional misuse, particularly of sedatives, opioids, and locally available psychoactive substances, exists, especially in urban slum areas and border regions. These substances may disrupt normal neurotransmitter synthesis, affecting dopamine and serotonin pathways, which are implicated in autism-related behaviors such as repetitive movement, sensory abnormalities, and impaired social interaction. Global studies have shown that drug misuse during pregnancy can alter fetal neural circuitry, increase inflammatory cytokines in neural tissue, and impair synaptic plasticity, all of which could contribute to neurodevelopmental vulnerabilities, including ASD-like traits. Even though such exposures are less prevalent in Bangladesh compared to Western countries, the risk still exists, particularly where access to medical supervision is limited and maternal awareness is low. More common in the Bangladesh context is medication misuse or improper medication use during pregnancy**,** especially in rural and low-income populations. While alcohol and drug-related ASD risk might be lower in Bangladesh, the unsupervised use of over-the-counter drugs, antibiotics, painkillers, anti-allergy medications, stomach acid suppressants, and sedatives poses neurodevelopmental risks. Many pregnant women, particularly in rural districts, self-medicate using drugs purchased directly from pharmacies without proper medical guidance. These medications are sometimes taken in inappropriate dosages or used for extended durations without knowing their potential risks to fetal brain development. Pregnant women often rely on advice from relatives, traditional healers, or non-certified drug sellers rather than qualified healthcare professionals. Some of these medications can interfere with fetal neurotransmitter development, sleep regulation, synaptic activity, and overall neuronal signaling, potentially leading to developmental disorders, cognitive deficits, or increased susceptibility to ASD like outcomes.

Mattson et al. (2019) emphasized that exposure to neurotoxic substances during pregnancy—including alcohol- can alter brain structure and reduce neural plasticity, especially during critical developmental windows. The authors explained that alcohol in particular changes the neuronal architecture by reducing synaptic density, altering neurotransmitter receptor configuration, and interfering with neuronal signal transmission (Mattson et al., 2019). Although research focusing specifically on medication misuse and ASD is still emerging, the biological mechanisms suggest that substances affecting brain signaling pathways, hormone balance, or placental function may increase the risk of neurodevelopmental issues. This means that even in settings such as Bangladesh, where alcohol and recreational drug use are rare improper medication use should be considered a potential neurodevelopmental risk factor**.**

Additionally, lack of awareness, social stigma, and limited access to prenatal counseling prevent many pregnant women in Bangladesh from receiving accurate information about safe and harmful medications. Many women do not receive antenatal education regarding harmful substances during pregnancy, nor do they have regular follow-up with healthcare professionals. This gap increases the risk of unintentional exposure to potentially harmful drugs during critical stages of fetal brain development. While alcohol and recreational drug use may remain limited due to cultural restrictions, medication misuse, improper dosage, and lack of supervision represent significant prenatal risks that may affect fetal neurological outcomes.

While Bangladesh has a culturally low prevalence of alcohol and recreational drug use during pregnancy, developmental risks remain through unsupervised medication use, exposure to sedatives, painkillers, and antibiotics**,** especially in rural and underserved areas. Prenatal exposure to these substances has the potential to alter fetal brain development through disrupted neurotransmission, impaired neuronal migration, inflammatory responses, and altered synaptic functioning (Mattson et al., 2019). Therefore, promoting safe medication practices during pregnancy and strengthening antenatal counseling are essential to protect fetal neurodevelopment and reduce the risk of autism-related vulnerabilities.

Chapter 4: Environmental and Surrounding Factors

4.1 Environmental and Dietary Exposure Findings

Environmental exposures during pregnancy have increasingly been recognized as key contributors to fetal neurodevelopmental outcomes. Unlike genetic predisposition, environmental influences, including pollutants, heavy metals, pesticides, and indoor household toxins, are largely modifiable and therefore represent crucial targets for prevention strategies. A growing body of evidence suggests that these environmental toxicants can cross the placental barrier, disrupt normal neural signaling, induce oxidative stress, interfere with neurotransmitter pathways, and provoke inflammatory processes mechanisms strongly associated with the etiology of Autism Spectrum Disorder (ASD) (Modabbernia et al., 2017). These exposures may not directly cause ASD but can significantly increase the vulnerability of the developing brain, especially when combined with maternal nutritional deficiencies, stress, or genetic susceptibility.

Heavy metals such as lead, mercury, and arsenic are among the most studied environmental risk factors for ASD. These metals can accumulate in maternal blood, cross the placental barrier, and interfere with synaptic development, myelination, and neuronal signaling. Lead exposure has been linked to impaired language, memory, and social interaction skills in children, while mercury exposure has been associated with cognitive deficits and behavioral abnormalities. Similarly, prenatal exposure to arsenic, which is prevalent in contaminated groundwater in Bangladesh, can cause disruptions in methylation-dependent gene expression, a process vital for neurodevelopment. These disruptions can influence brain regions linked to communication, sensory processing, and emotional regulation, all commonly affected in individuals with ASD (Modabbernia et al., 2017). Air pollution is another emerging environmental risk linked to ASD. Pollutants such as particulate matter (PM2.5), nitrogen dioxide, and ozone can generate oxidative stress and inflammatory responses in both the mother and fetus. These toxins not only affect fetal brain development but may also trigger maternal immune activation, which has been shown to alter neural development pathways. Studies have suggested that children born to mothers with high exposure to air pollution are more likely to develop ASD traits. In regions like Bangladesh, where rapid urbanization and industrial emissions are prevalent, pregnant women are particularly vulnerable in urban centers such as Dhaka and Gazipur, which experience high levels of exposure to air pollution. Environmental exposures during pregnancy, such as heavy metals, pesticides, household pollutants, and poor indoor air quality, pose significant risks to fetal neurodevelopment and have been increasingly associated with Autism Spectrum Disorder (ASD). Long-term exposure to heavy metals like lead, mercury, arsenic, and cadmium can disrupt neuronal migration, impair synaptic development, and increase oxidative stress, ultimately affecting cognitive and behavioral outcomes (Modabbernia et al., 2017). Pesticide exposure is another notable risk factor, particularly in Bangladesh where agricultural workers often lack proper protective equipment and safety regulations. Organophosphate pesticides are known to interfere with key neurotransmitter systems such as acetylcholine and GABA, which play critical roles in neural signaling and brain development. These chemicals can alter neuronal differentiation and synaptic function, leading to developmental delays and increased ASD susceptibility.

Indoor environmental toxins further compound these risks. In many Bangladeshi households, pregnant women are frequently exposed to smoke from biomass fuels (wood, charcoal, cow dung), kerosene, mosquito coils, plastics, and chemical household products. These exposures generate harmful pollutants, including carbon monoxide, particulate matter (PM2.5), volatile organic compounds (VOCs), and neurotoxic residues. When inhaled, these particles can enter the maternal bloodstream and cross the placental barrier, reducing fetal oxygen supply and causing inflammation and oxidative damage that impair brain development. Alarmingly, burning mosquito coils indoors, which is common in Bangladesh, can release toxic emissions equivalent to approximately 100 cigarettes in a single night, exposing both mothers and fetuses to hazardous levels of irritants and neurotoxins.

These environmental exposures activate maternal immune responses and escalate inflammatory cytokine levels, contributing to the "maternal immune activation" pathway linked to increased ASD risk. Chronic exposure to these pollutants disrupts neurogenesis, alters neurotransmitter balance, and interferes with critical brain development stages such as synaptic pruning and myelination. In Bangladesh, these risks are intensified by socio-environmental factors including inadequate ventilation, lack of awareness, poor prenatal care, rapid urbanization, and unregulated agricultural practices. Furthermore, overlapping nutritional deficiencies, such as low folate, vitamin D, and omega-3 levels, may worsen the neurodevelopmental impact of environmental toxins.

In summary, prenatal exposure to heavy metals, pesticides, household smoke, and indoor pollutants significantly contributes to ASD susceptibility by triggering inflammation, oxidative stress, hypoxia, and disrupted neurotransmitter signaling (Modabbernia et al., 2017). In the Bangladeshi context, these dangers are amplified by poor indoor air quality, unsafe cooking fuels, widespread mosquito coil use, and inadequate maternal health education. Addressing these risks requires strengthening environmental health regulations, promoting clean cooking technologies, raising public awareness, and integrating environmental risk assessment into antenatal care systems to protect fetal brain development and reduce ASD risk.

Environmental Risk Factor	Global Context	Bangladesh-Specific Context	Global References	Bangladesh / Regional References
Air Pollution (PM2.5, PM10, NO_2, SO_2)	Associated with oxidative stress, maternal inflammation, placental dysfunction, and impaired fetal neurodevelopment.	PM2.5 levels in Dhaka, Gazipur, Narayanganj, and Chattogram exceed WHO limits by 10–15 times due to brick kilns, traffic emissions, industrial activity, and waste burning.	WHO (2021); Raz et al. (2015); Perera et al. (2019)	Begum et al. (2013); World Bank (2022) Bangladesh Air Quality Report; Khan et al. (2019)
Heavy Metals (Lead, Arsenic, Mercury)	Prenatal exposure causes neurotoxicity, impaired synaptic development, and long-term cognitive deficits.	Arsenic contamination in groundwater affects millions; lead exposure from paint, spices, cosmetics, toys, battery recycling, and industrial soil contamination.	Grandjean & Landrigan (2014); WHO (2017); Wasserman et al. (2004)	Rahman et al. (2018); UNICEF Bangladesh (2019); Flanagan et al. (2012)
Pesticides (Organophosphates, Glyphosate)	Linked to disrupted neurotransmission, altered gene expression, and increased ASD-related traits.	Extensive agricultural use with weak regulation; high exposure among rural women, often without protective equipment.	Shelton et al. (2014); Rauh et al. (2011)	Chowdhury et al. (2012); World Bank (South Asia pesticide exposure reports)
Indoor Air Pollution (Biomass Smoke, CO, VOCs)	Major contributor to maternal and fetal health risks in low-income settings.	Over 50% of rural and low-income urban households rely on wood, cow dung, or coal for cooking, increasing prenatal exposure.	WHO (2018); Smith et al. (2014)	NIPORT et al. (2019); Das et al. (2020)
Mosquito Coil & Insecticide Fumes	Limited global focus; exposure linked to respiratory and neurological effects.	Widely used in households; one mosquito coil emits particulate matter equivalent to ~100 cigarettes; releases	Liu et al. (2003); WHO (2010)	Saha et al. (2018); Bangladesh DoE reports

Environmental Risk Factor	Global Context	Bangladesh-Specific Context	Global References	Bangladesh / Regional References
		neurotoxic pyrethroids.		
Plastic & Phthalate Exposure (BPA, Phthalates)	Endocrine-disrupting chemicals associated with neurodevelopmental disorders and ASD risk.	High use of low-cost plastics and cosmetics, often unregulated and unlabeled.	Braun et al. (2011); Trasande et al. (2020)	Hossain et al. (2021); Bangladesh Food Safety Authority reports
Noise Pollution & Urban Stress	Chronic prenatal stress affects fetal brain development via cortisol dysregulation.	High maternal stress from traffic congestion, noise pollution, overcrowding, and socioeconomic pressure in urban areas.	Van den Bergh et al. (2017); WHO (2018)	Ahmed & Hossain (2020); Dhaka city environmental studies
Industrial Chemicals & Factory Emissions	Exposure common in industrial zones; linked to neurodevelopmental toxicity.	Textile factories, brick kilns, tanneries, and metal workshops expose pregnant women to lead, chromium, and other toxicants.	Landrigan et al. (2018)	Human Rights Watch (Bangladesh); Akter et al. (2014)
Access to Clean Air & Green Space	Green spaces improve maternal mental health and pregnancy outcomes.	Extremely limited in Dhaka and Gazipur; minimal safe outdoor environments for pregnant women.	WHO (2017); Markevych et al. (2017)	Kabir et al. (2020); RAJUK urban planning reports

Table 04: Comparison of Global vs. Bangladesh-Specific Environmental ASD Risk Factors

4.2 Air Pollution and Heavy Metals

Outdoor Air Pollution (PM2.5, PM10, NO_2, CO)

Outdoor air pollution is one of the most strongly documented environmental risk factors for autism in babies at birth. Fine particulate matter (PM2.5) penetrates deeply into the lungs and bloodstream, generating maternal systemic inflammation and oxidative stress. These inflammatory markers can reach the fetus, affecting neurogenesis and cortical development (Perera et al., 2019). Studies from the U.S., Canada, China, and Europe show that prenatal exposure to PM2.5 and NO_2 is associated with increased ASD risk (Raz et al., 2015). Exposure in the third trimester appears most damaging due to rapid brain growth and synaptogenesis.

Bangladesh is consistently ranked among the most polluted countries in the world, with Dhaka, Gazipur, Narayanganj, and Chattogram frequently recording PM2.5 concentrations 8–10 times higher than WHO safety limits. Maternal exposure to such severe air pollution during pregnancy increases the risk of low birth weight, preterm birth, and impaired cognitive development, which are factors strongly associated with Autism Spectrum Disorder (ASD) (Perera et al., 2019). Industrial emissions, brick kilns, vehicular exhaust, and unplanned urbanization significantly intensify air quality degradation, creating a hazardous environment for maternal and fetal health. Addressing air pollution is therefore crucial for protecting neurodevelopmental outcomes in Bangladesh.

Heavy Metals (Lead, Arsenic, and Mercury) and Autism Spectrum Disorder Risk

Heavy metals like lead (Pb), arsenic (As), and mercury (Hg) are some of the most thoroughly researched environmental neurotoxins that can profoundly affect fetal brain development. The presence of these metals can penetrate the placental barrier and build up in fetal tissues, disrupting essential neurodevelopmental processes such as neuronal differentiation, synaptic formation, and neurotransmitter regulation (Modabbernia et al., 2017). In comparison with genetic risks, exposure to heavy metals is primarily influenced by environmental factors and can be altered, highlighting its significance as a public health issue, particularly in developing nations like Bangladesh. Study evidence indicates that exposure to heavy metals during prenatal development can hinder synaptic pruning, disrupt cortical connectivity, and result in behavioral and cognitive deficits that mirror traits that are related to Autism Spectrum Disorder (ASD), such as challenges in social interaction, communication issues, and repetitive behaviors (Christensen et al., 2019).

Exposure to lead (Pb) is notably detrimental as it disrupts synaptic signaling, blocks dendritic growth, and negatively affects neurotransmitter functions, including those associated with dopamine and glutamate pathways, which are essential for attention, behavior regulation, and emotional processing (Christensen et al., 2019). Exposure to lead during prenatal development has been linked to symptoms resembling autism spectrum disorder, attention deficit hyperactivity disorder, reduced IQ, and various behavioral issues. Lead poses significant dangers as it imitates calcium, interfering with neuronal firing and synaptic plasticity. In Bangladesh, the prevalence of lead contamination is significant, largely stemming from unregulated battery recycling, the use of lead-based paint, contaminated turmeric, industrial emissions, and polluted soil. Random recycling workshops, often found in Dhaka, Gazipur, and Narayanganj, put pregnant women in high-risk situations. Furthermore, lead-contaminated turmeric has been recognized as a significant source of exposure in Bangladesh, leading to neurodevelopmental risks for pregnant women and young children.

In Bangladesh, the presence of arsenic (As) in naturally contaminated groundwater presents a significant risk. Bangladesh stands out as one of the most severely impacted countries by arsenic contamination, with millions depending on tube wells tainted with arsenic for their daily drinking and cooking needs. Chronic exposure to arsenic has the potential to interfere with neuronal signaling, impair mitochondrial function, modify gene methylation, and trigger oxidative stress factors that are associated with neurodevelopmental abnormalities related to ASD (Rahman et al., 2017). The impact of arsenic on mitochondrial DNA results in disrupted energy regulation within brain cells, which may reduce synaptic connectivity and threaten neuronal survival. Prolonged exposure to arsenic has been linked to diminished cognitive abilities, decreased processing speed, delays in speech development, and issues with emotional regulation in children. The behavioral deficits identified align closely with the fundamental symptoms seen in ASD, highlighting arsenic as a major environmental concern in Bangladesh.

Exposure to mercury (Hg) mainly happens through the intake of contaminated fish and contact with industrial waste and emissions. Mercury serves as a powerful neurotoxin, capable of hindering neuronal migration, interfering with neurotransmitter release, and causing damage to the myelin sheaths that encase nerve cells. The primary impact is on the cerebellum, cortex, and hippocampus, which are crucial for motor skills, memory, language, and social cognition. In Bangladesh, there are growing reports of mercury contamination in fish sourced from polluted rivers such as the Buriganga, Turag, and Karnaphuli. Expectant mothers face potential risks as fish serves as a key protein source, particularly in fishing communities and coastal regions. While fish are rich in nutrients, those contaminated with methylmercury can present neurodevelopmental hazards, especially during the critical period of fetal brain development.

4.3 Household and Occupational Exposure

Indoor Air Pollution (Biomass Fuel, Kerosene, Charcoal)

Indoor air pollution is a major concern for the environment in Bangladesh, but not many people know about it. This is especially true for poor and rural families. More than 30% of Bangladeshi homes use biomass fuels like wood, cow dung, charcoal, and agricultural waste to cook and heat their homes. Whenever these fuels burn, they release a lot of hazardous substances such as carbon monoxide (CO), sulfur dioxide (SO_2), formaldehyde, nitrogen oxides, and fine particulate matter (PM2.5 and PM10). These pollutants build up in indoor spaces that aren't well-ventilated, which makes pregnant women very susceptible to being around them all the time. Biomass smoke can enter the bloodstream through inhalation and cross the placental barrier, compromising fetal oxygen supply, disrupting placental function, and affecting neural development (Khan et al., 2019).

Receiving around indoor pollutants while pregnant can cause maternal hypoxia, a condition in which is when the mother's oxygen levels drop and affect the oxygen supply to the fetus. Maternal hypoxia is linked with impaired brain oxygenation, altered synaptic development, and abnormal myelination in the developing fetal brain. Pollutants like carbon monoxide bind tightly to the hemoglobin, which makes it less able to carry oxygen. This may result in chronic intrauterine hypoxia, which can lead to developmental delays, low birth weight, and a higher chance of neurodevelopmental disorders in the fetus, such as traits corresponding to ASD (Khan et al., 2019). Sulfur dioxide and fine particulate matter can also cause systemic inflammation and oxidative stress, which can lead to problems with the placenta. When placental efficiency is reduced, nutrient transport, oxygen delivery, and hormonal regulation are negatively affected, which can impair fetal neurodevelopment.

Indoor air pollution has also been linked to preterm birth and low birth weight nowadays, both of which are known risk factors for ASD. Babies who are born too early or with a low birth weight often have challenges with neuronal connectivity, language development, and thinking. These results are similar to those of people with ASD, which suggests that indoor pollution may make people more likely to get ASD. Khan et al. (2019) reported that exposure to indoor biomass smoke during pregnancy significantly increases the risk of respiratory distress, premature birth, and impaired neurodevelopment in infants. Further, inflammation resulting from exposure to pollutants may disrupt neurotransmitter function and the structural development of the brain, thereby exacerbating behavioral susceptibility associated with ASD. In Bangladesh, indoor air pollution is a bigger problem than outdoor pollution in many rural and poor urban homes. Women, especially pregnant women, spend a lot of time near cooking stoves every day, often in kitchens that don't get enough air. Long exposure can be caused by a lack of exhaust systems, too many individuals living in one place, and not enough knowledge.

Although indoor air pollution is frequently neglected in autism research, its impact on hindering fetal brain growth through hypoxia, inflammation, placental dysfunction, and an elevated risk of adverse birth outcome which indicates an indirect association with ASD risk (Khan et al., 2019). Reducing indoor air pollution through improved cooking practices, cleaner fuels, and ventilation strategies may help improve maternal health and reduce neurodevelopmental risks in children.

Household Chemicals (Mosquito Coils, Insect Sprays, Disinfectants)

Household chemical exposure represents a significant but often overlooked environmental risk factor for Autism Spectrum Disorder (ASD), especially in low- and middle-income countries like Bangladesh. Bangladeshi households commonly use mosquito coils, aerosol insect sprays, antiseptic cleaners, bleaching agents, naphthalene balls, and chemical air fresheners daily. These days, every house uses these things to deal with its daily problems. These products emit volatile organic compounds (VOCs), pyrethroids, formaldehyde, phenols, and other neurotoxic substances that remain suspended in indoor air for extended periods. Prolonged exposure during pregnancy can allow these toxins to cross the placental barrier, interfere with fetal immune and neural development, and increase susceptibility to neurodevelopmental disorders (Hossain et al., 2022).

Mosquito coils are among the most widely used insect control products in Bangladesh. Burning one mosquito coil produces smoke equivalent to approximately 100 cigarettes, releasing fine particulate matter, carbon monoxide, and pyrethroid insecticides. Pyrethroids are known neurotoxins that interfere with sodium ion channels in neuronal cells, altering neurotransmitter transmission and triggering neuroinflammation. A recent Bangladesh-based case–control study found that children diagnosed with ASD were significantly more likely to have been prenatally exposed to mosquito coil smoke and aerosol insect sprays compared to neurotypical children

(Hossain et al., 2022). These findings highlight the potential role of indoor chemical exposure as a modifiable environmental risk factor for ASD.

Additionally, aerosol sprays, antiseptic surface cleaners, naphthalene balls, and bleaching agents contain compounds such as benzene, ammonia, paradichlorobenzene, and phenols. These substances may affect fetal brain development by promoting oxidative stress, altering neural cell differentiation, and disrupting hormonal signaling pathways. During critical periods of pregnancy, exposure to these chemicals can interfere with synaptic development, myelination, and neurotransmitter formation, contributing to developmental delays and ASD-like traits (Hossain et al., 2022).

Household chemical exposure poses a greater risk due to poor ventilation, as most of house owners use air-conditioning, frequent indoor use, lack of regulatory oversight, and minimal public awareness. Pregnant women, particularly homemakers, are disproportionately affected due to prolonged indoor exposure. Reducing household chemical exposure through safer alternatives, ventilation improvement, and maternal education could help mitigate ASD risk among Bangladeshi children.

Parental Occupation and Industrial Exposure

Exposure to pesticides, solvents, textile dyes, heavy metals, and construction dust in the workplace while pregnant has been linked to a higher risk of ASD (Lyall et al., 2017). In Bangladesh, workers in garment factories, informal recycling plants, tanneries, and shipbreaking yards experience significant toxic exposure, impacting not only maternal factors but also paternal occupational contributions to ASD susceptibility.

4.4 Pesticides and Contaminated Water

Pesticides disrupt fetal brain development by inhibiting acetylcholinesterase, damaging mitochondrial function, and altering gene expression. Maternal exposure to organophosphate pesticides is strongly associated with ASD, particularly in agricultural communities (Bouchard et al., 2011). In Bangladesh, the use of pesticides is rising quickly, and people often don't have the right protective equipment or rules in place. In environments where crops are grown, like vegetable fields in Savar, Narsingdi, and Jessore; rice fields in Rajshahi and Bogura; and fruit orchards in Dinajpur and Chuadanga, heavy pesticide spraying leaves behind toxic chemicals that get into the food chain and make pregnant women more susceptible to harm Bangladesh, particularly due to the presence of arsenic, lead, and other toxic metals originating from natural deposits and industrial pollution. More than 27% of tube wells in Bangladesh contain arsenic levels above the World Health Organization's safety limit, making it one of the most severely arsenic-affected countries globally (Rahman et al., 2017). In addition, unregulated waste disposal from tanneries, textile dyeing facilities, and pharmaceutical industries releases harmful substances such as chromium, lead, cadmium, and mercury into rivers and groundwater. These contaminants enter household water supplies used for drinking, cooking, and washing, increasing exposure risks, especially among pregnant women.

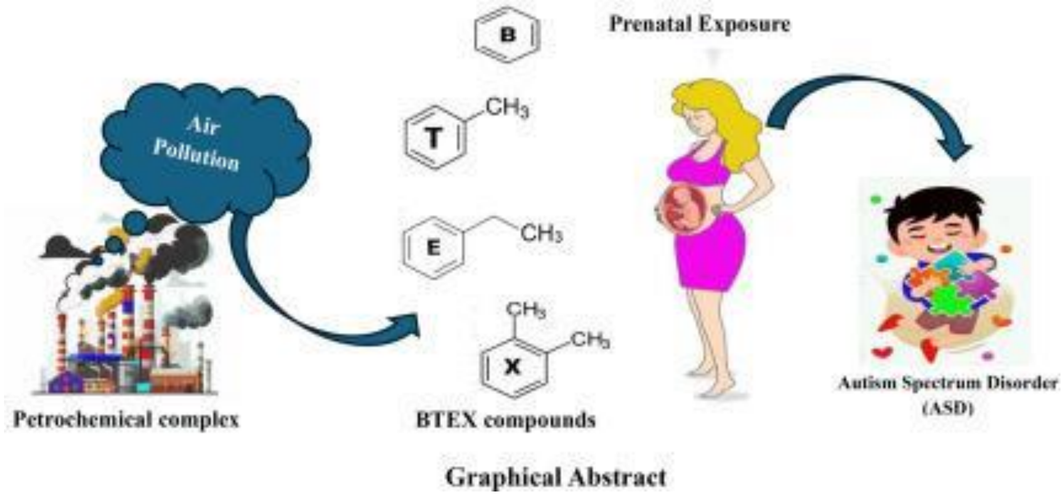

Figure 05: Prenatal exposure to benzene, toluene, ethylbenzene, and xylene (BTEX) and the risk of autism spectrum disorders in children. (Hashemi et al., 2025)

Prenatal exposure to contaminated water poses serious risks to fetal brain development and may contribute to ASD-related outcomes. Arsenic contamination, common in many parts of Bangladesh, disrupts neuronal signaling, alters DNA methylation patterns, and increases oxidative stress, all of which interfere with proper synaptic formation and brain maturation (Rahman et al., 2017). Long-term arsenic exposure has been linked to speech delay, impaired cognitive function, behavioral challenges, and social communication difficulties, symptoms frequently associated with Autism Spectrum Disorder (ASD). Similarly, lead contamination in drinking water, particularly reported in Dhaka, Narayanganj, Savar, and Gazipur due to industrial effluents, battery recycling, and poor waste management, is a major neurodevelopmental concern. Lead can easily cross the placental barrier and disrupt neuronal migration, neurotransmitter balance, and dendritic growth, contributing to ASD-like features such as attention problems, communication difficulties, and repetitive behaviors (Rahman et al., 2017).

Mostly Industrially polluted rivers in Bangladesh such as the Buriganga, Turag, and Karnaphuli are widely used for irrigation, resulting in the accumulation of heavy metals in commonly consumed foods, including rice, fish, and vegetables. Pregnant women consuming these contaminated foods are indirectly exposed to toxic elements, which can impair placental function, reduce oxygen and nutrient delivery to the fetus, and increase the risk of low birth weight and preterm birth, both established ASD risk factors. Overall, exposure to arsenic, lead, and other heavy metals through water and diet in Bangladesh may contribute to ASD susceptibility through mechanisms involving oxidative stress, disrupted synaptic development, placental dysfunction, and impaired cognitive processing (Rahman et al., 2017).

Chapter 5: Bangladesh-Specific Risk Factors

5.1 Maternal Nutrition Status in Bangladesh

The country of Bangladesh presents a one-of-a-kind combination of issues relating to diet, the environment, lifestyle, and healthcare that have an impact on the physiological development of the embryo and the health of the mother. Although research conducted on a global scale has identified several prenatal risk factors for Autism Spectrum Disorder (ASD), the situation in Bangladesh is distinct due to the country's high population density, severe air pollution, heavy metal poisoning, widespread nutritional inadequacies, and socioeconomic vulnerabilities. These factors may interact with one another in a way that will increase the likelihood of neurodevelopmental problems, such as autism spectrum disorder (ASD). Evidence gathered from Bangladesh regarding maternal diet, lifestyle, and environmental exposures, with a focus on risk factors that are specific to the characteristics of the region in which they live.

Bangladesh continues to face a substantial burden of micronutrient deficiencies among pregnant women, which poses serious implications for fetal neurodevelopment and potential ASD vulnerability. National health surveys indicate that approximately 40–47% of pregnant women in Bangladesh are anemic, primarily due to iron deficiency, poor dietary diversity, and limited access to prenatal supplements (NIPORT, 2020). Iron plays a vital role in oxygen transport, myelination, and neurotransmitter synthesis, and inadequate levels during pregnancy can impair fetal brain development, leading to behavioral and cognitive challenges commonly observed in Autism Spectrum Disorder (ASD). In addition to iron deficiency, 35–38% of Bangladeshi pregnant women have iodine deficiency, a crucial micronutrient required for thyroid hormone production, neuronal migration, and synaptic development. Iodine deficiency during pregnancy is strongly associated with impaired cognitive function, delayed speech, memory deficits, and neurodevelopmental impairments that overlap with ASD-related symptoms (NIPORT, 2020).

Moreover, Vitamin D deficiency affects more than 60% of pregnant women in Bangladesh, a striking statistic considering the country's abundant sunlight (Islam et al., 2021). Factors such as indoor lifestyles, air pollution blocking UV-B rays, cultural clothing practices, and lack of awareness about supplementation contribute to widespread deficiency. Vitamin D plays a critical neuroprotective role by regulating neuronal differentiation, calcium signaling, immune modulation, and anti-inflammatory responses. Inadequate levels can disrupt the development of neural networks and increase inflammatory cytokines, both of which are linked to ASD pathophysiology (Mazahery et al., 2019). Similarly, folate deficiency remains common due to low consumption of green leafy vegetables, legumes, and fortified foods. Folate is essential for DNA methylation, cell division, and neural tube formation. Deficiency during early pregnancy can lead to neural tube defects, abnormal neuronal signaling, and potential autism-related complications (Mazahery et al., 2019).

Bangladesh faces a unique combination of nutritional vulnerabilities and environmental challenges, making pregnant women more susceptible to neurodevelopmental risks. The coexistence of micronutrient deficiencies with poor dietary diversity, anemia, environmental toxins, and limited access to maternal healthcare creates a high-risk scenario for fetal neurodevelopment. Since these deficiencies are modifiable through nutrition education, supplementation, and public health strategies, addressing them could play a vital role in reducing ASD risk in Bangladesh.

Poor Dietary Diversity

Maternal change in diet is essential for maintaining sufficient nutrient intake for successful embryonic brain development. However, previous research indicates pregnant women in Bangladesh often eat the same kind of meals over and over, mostly rice, lentils, and potatoes, with very few nutrient-rich foods like fish, eggs, milk, fruits, and green leafy vegetables (Ahmed et al., 2020). This diet fails to provide the body with enough of the important micronutrients it needs for embryonic neurodevelopment, like folate, iron, omega-3 fatty acids, vitamin D, and zinc. These nutrients are needed for neural tube formation, connective tissue development, neurotransmitter synthesis, and myelination. Many pregnant women in rural regions eat less than five different types of food each day. This is much below the World Health Organization's (WHO) recommended level of dietary diversity. Such a lack of variety in the diet raises the likelihood of neurological disorders in children, such as Autism Spectrum Disorder (ASD), because the mother didn't get enough micronutrients during important times of pregnancy. Several socioeconomic and cultural factors have been linked to the lack of dietary diversity in Bangladesh. These include poverty, limited access to nutrient-rich foods, lack of knowledge about prenatal nutrition, and traditional food practices that prioritize essential grains ahead of animal-sourced foods. Many women, especially those who live in rural areas or have poor incomes, depend on rice-based meals for energy. They don't eat fruits, vegetables, or animal proteins very often because they are too expensive or they don't like them. These nutrition habits frequently continue during pregnancy, resulting in nutritional deficiencies, anemia, and maternal malnutrition, which may impact fetal brain development and long-term cognitive results. Despite Bangladesh being rich in fish resources, the consumption of fish among pregnant women remains relatively low, resulting in inadequate intake of omega-3 fatty acids such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), which are essential for fetal brain and cognitive development. Limited consumption of green leafy vegetables further contributes to folate deficiency, while insufficient intake of dairy products leads to inadequate calcium and vitamin D levels. These nutritional deficiencies have been associated with neuroinflammation, disrupted neurotransmitter function, and atypical neuronal development, thereby creating biological conditions that may increase the risk of autism spectrum disorder (ASD). Moreover, the predominance of cereal-based diets combined with low intake of nutrient-dense foods among Bangladeshi pregnant women may adversely affect fetal brain development. Addressing poor dietary diversity through nutrition education, improved food affordability, and policy-level nutritional interventions is therefore crucial for reducing the future risk of ASD in the Bangladeshi population (Ahmed et al., 2020).

Food Contamination and Heavy Metals

Food poisoning with heavy metals has become a major public health issue in Bangladesh, especially because it could affect the brain development of unborn babies. Numerous studies have indicated the presence of hazardous metals, including arsenic, lead, and mercury, in typical Bangladeshi staple foods, which raises concerns over dietary exposure among pregnant women (Jahan & Hossain, 2020). Arsenic poisoning in rice—the most extensively consumed staple grain in Bangladesh is particularly concerning due to its absorption of arsenic from groundwater and soil in southern and central regions. Consistent consumption of arsenic during pregnancy may interfere with neuronal signaling, mitochondrial function, and DNA methylation, thereby elevating the risk of neurodevelopmental disorders, such as ASD. Another big worry is lead contamination in turmeric, vegetables, and spices. According to reports, lead chromate is used in Bangladesh to make turmeric seem more yellow, which means that turmeric powder sold in stores has a lot of lead in it (Jahan & Hossain, 2020). Also, vegetables cultivated near manufacturing plants often take up lead from the soil and water used for irrigation. Lead is a suspected neurotoxic that disrupts synaptic function, neurotransmitter modulation, and cortical brain development, potentially exacerbating behavioral and cognitive abnormalities associated with ASD (Rahman et al., 2017). Lead exposure during pregnancy has been linked to attention difficulties, delayed speech, and poor learning abilities in children, symptoms that are similar to those of autism spectrum disorder (ASD). People who live near rivers and coasts are more likely to be exposed to mercury through seafood that has been poisoned. Due to effluent discharge from tanneries, dyeing factories, and chemical industries, fish from rivers that are polluted by industry, like the Buriganga, Turag, and Karnaphuli, have higher levels of mercury (Jahan & Hossain, 2020). Mercury interferes with neuronal migration, neurotransmitter equilibrium, and synaptic maturation during fetal brain development, heightening the likelihood of neurodevelopmental disorders (Rahman et al., 2017). In Bangladesh, pregnant women eat a lot of fish, which is a primary source of protein. Eating seafood that has been polluted with mercury regularly is a hidden risk to development. The toxins can get through the placenta and build up in the tissues of the fetus, which can disrupt important stages of brain development. Exposure to heavy metals during pregnancy may have lasting effects on cognition, behavior, and communication, thereby increasing the risk of ASD in Bangladeshi children (Rahman et al., 2017). These findings underscore the necessity of raising food safety, monitoring contamination, and spreading knowledge among pregnant women concerning preventable neurological development risks.

5.2 Environmental Health and Social Challenges

Bangladesh's rapid industrialization and urbanization have substantially increased environmental pollution, thereby elevating population-level exposure to neurotoxic chemicals that may adversely affect fetal brain development. Major industrial hubs such as Dhaka, Chattogram, Gazipur, and Narayanganj host dense clusters of textile factories, tanneries, brick kilns, cement plants, dyeing units, and pharmaceutical industries, which release significant quantities of heavy metals, volatile organic compounds (VOCs), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter (PM2.5 and PM10) into the surrounding air, soil, and water (Hossain et al., 2019; World Health Organization [WHO], 2021). Pregnant women residing in these industrialized areas are chronically exposed to these toxic substances through inhalation, ingestion, and dermal contact, increasing the likelihood of placental transfer and disruption of embryonic neurodevelopment (Grandjean & Landrigan, 2014).

Air pollution represents a particularly severe public health concern in Bangladesh, with Dhaka frequently ranked among the cities with the highest PM2.5 concentrations globally (IQAir, 2023; WHO, 2021). Fine particulate matter originating from vehicular emissions, brick kilns, construction activities, and industrial sources often contains neurotoxic metals such as lead, cadmium, arsenic, manganese, and mercury. Prenatal exposure to these pollutants has been associated with oxidative stress, neuroinflammation, mitochondrial dysfunction, abnormal synaptic development, and altered neurotransmitter signaling mechanisms strongly implicated in the etiology of autism spectrum disorder (ASD) (Becerra et al., 2013; Volk et al., 2013). Consequently, sustained exposure to high levels of air pollution during pregnancy may increase the risk of ASD-related cognitive and behavioral outcomes in children.

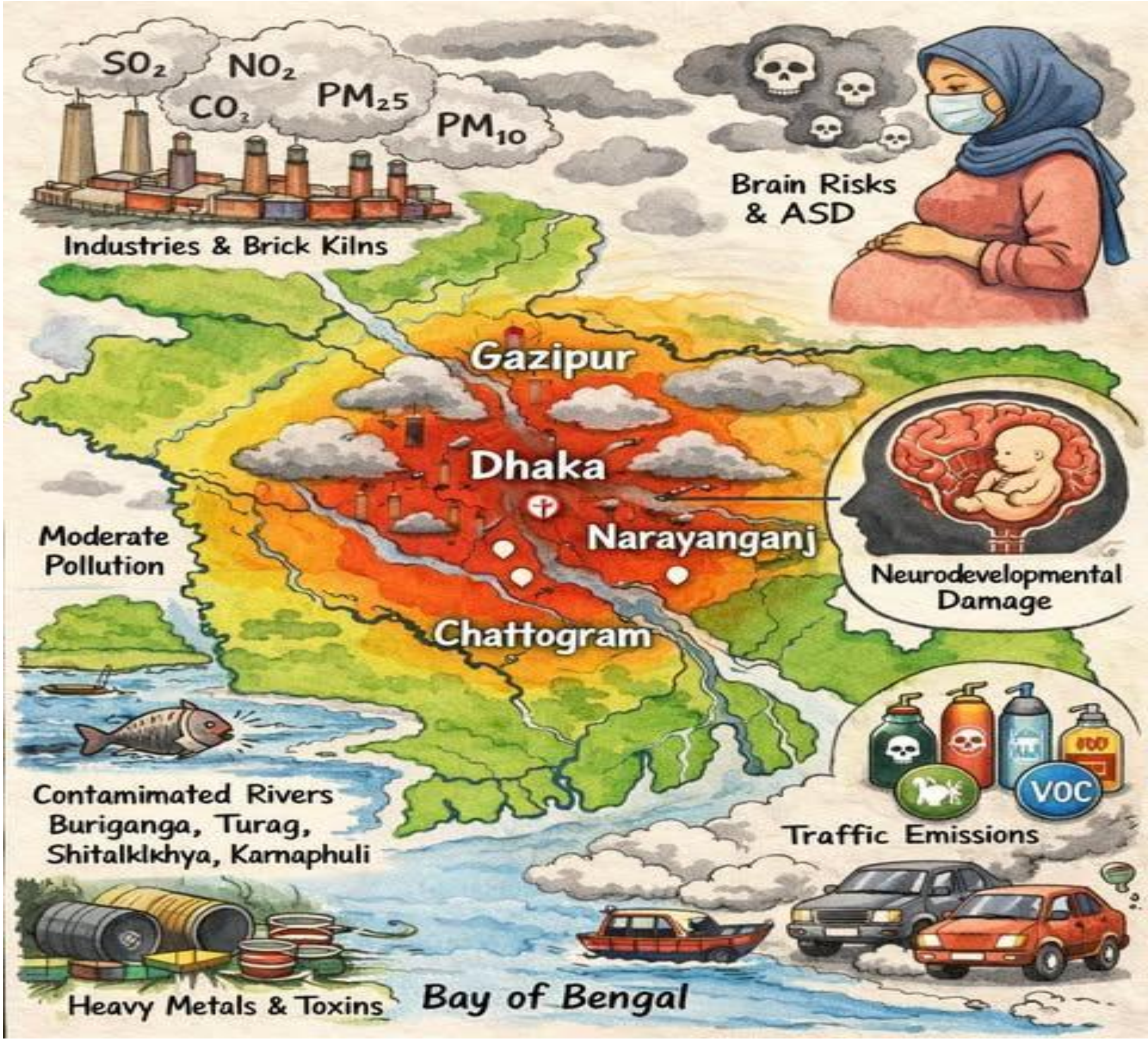

Figure 06: Bangladesh Urban Air pollution risk PM2.5 **zone map (Dhaka, Narayanganj, Gazipur, Chattagram)**

Additionally, major rivers in Bangladesh, including the Buriganga, Turag, Shitalakkhya, and Karnaphuli which serve as critical sources of water for agriculture, household use, and fisheries, are heavily contaminated by untreated industrial effluents (Islam et al., 2015; World Health Organization [WHO], 2021). Pregnant women may be indirectly exposed to toxic heavy metals and chemical residues through the consumption of contaminated fish, vegetables, and crops, as these pollutants tend to bioaccumulate within aquatic and agricultural food chains (Rahman et al., 2019). Such exposure during pregnancy poses significant risks to fetal neurodevelopment due to the ability of many heavy metals to cross the placental barrier.

In addition to outdoor and water pollution, indoor chemical exposure represents an emerging concern in urban and commercial environments. The widespread use of chemical air fresheners, paints, detergents, bleaching agents, mosquito coils, and aerosol sprays contributes to indoor air contamination with volatile organic compounds, including benzene, toluene, ethylbenzene, and xylene (BTEX) (WHO, 2010). Prenatal exposure to BTEX compounds during critical periods of brain development has been associated with neurotoxicity, altered neuronal signaling, and increased risk of neurodevelopmental disorders, including autism spectrum disorder (ASD) (Grandjean & Landrigan, 2014; Jedrychowski et al., 2015).

Aspect	Urban areas (Dhaka, Gazipur, Narayanganj, Chattogram)	Rural areas (villages, upazilas)
Main pollution sources	Vehicle exhaust, brick kilns, textile & tannery industries, construction dust, generators, and household chemical emissions (Hashemi et al., 2025).	Biomass cooking fuel (wood, dung, crop residue), agricultural pesticides, open waste burning, and small brick kilns (NIPORT, 2020).
$PM_{2.5}$ levels	Average $PM_{2.5}$ in Dhaka ≈ 83–86 µg/m³ (4–9× higher than WHO limit); some studies report seasonal peaks up to 112 µg/m³ (WHO, 2020).	Lower than cities but still above WHO guideline during dry season and crop-burning periods (WHO, 2020).
Household fuel	Predominantly LPG/natural gas, but slums continue biomass use (NIPORT, 2020).	75–90% of households use wood, dung, or crop residue as primary cooking fuel (NIPORT, 2020).
Typical indoor exposures	Mosquito coils, aerosol sprays, detergents, solvents, paints, BTEX compounds, indoor smoking (Hashemi et al., 2025).	Biomass smoke in poorly ventilated kitchens, pesticide storage, minimal chemical cleaning products (Rahman et al., 2017).
Key neurodevelopmental concerns	Chronic exposure to $PM_{2.5}$, NO_2, sulfur dioxide, and heavy metals → oxidative stress, neuroinflammation, and increased ASD risk (Hashemi et al., 2025).	Biomass smoke exposure → maternal hypoxia, preterm birth, low birth weight, delayed cognitive development (Rahman et al., 2017).
Vulnerability of pregnant women	Frequent exposure to outdoor and indoor air pollution; close proximity to industrial clusters (Hashemi et al., 2025).	Prolonged exposure to kitchen smoke; less access to healthcare and maternal nutrition education (NIPORT, 2020).

Table 05: Urban vs Rural Pollution Risk in Bangladesh

Urban pregnant women in Bangladesh are further burdened by stress, noise pollution, overcrowding, heat exposure, and limited access to healthcare services. These environmental and socioeconomic stressors may interact with chemical exposures, leading to compounded risks to fetal neurodevelopment. Overall, in recent studies researcher found industrial and urban pollution in Bangladesh represents a significant maternal risk factor that may contribute to the rising prevalence of neurodevelopmental disorders, including autism, in the country. The pie chart illustrates that autism prevalence is higher in urban areas (25 per 10,000) compared to rural regions (14 per 10,000), indicating a greater concentration of ASD cases among children living in urban settings in Bangladesh (Akhter et al., 2024)

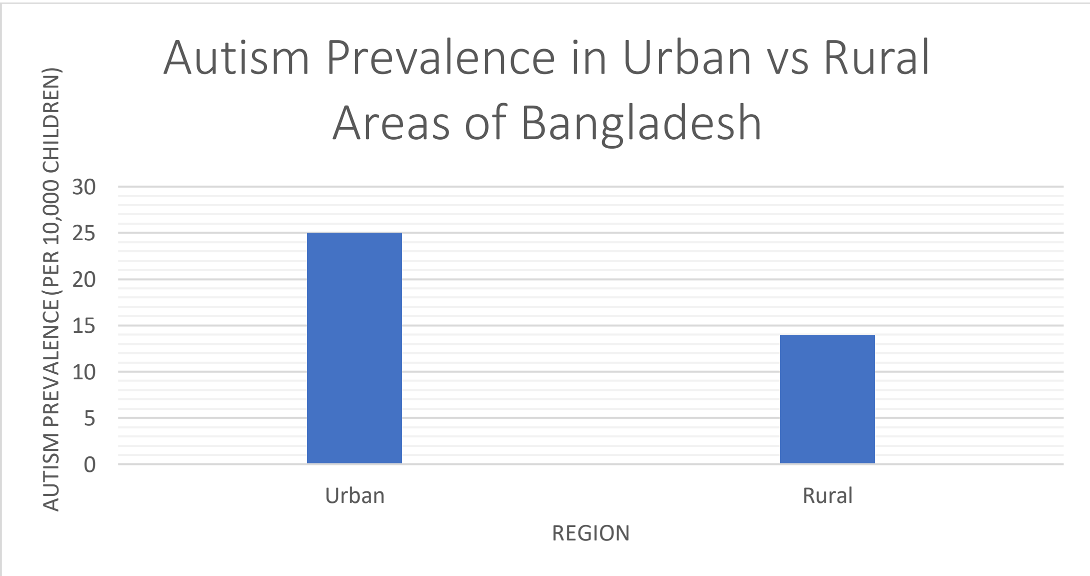

Figure 07: Autism prevalence in urban (25 per 10,000) and rural (14 per 10,000) areas of Bangladesh (Akhter et al., 2024).

Air Pollution: A Major ASD-Linked Risk

Bangladesh has consistently ranked among the world's most polluted nations, with major cities such as Dhaka, Gazipur, Narayanganj, and Chattogram recording dangerously high levels of particulate and gaseous pollutants. In these areas, pregnant women are exposed to dangerous levels of fine particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide (SO_2) from thermal power plants, nitrogen oxides (NO_x) from car emissions, and black carbon from brick kilns. These pollutants can cross the placental barrier, which causes oxidative stress, systemic inflammation, and placental dysfunction, potentially interfering with fetal brain development. Studies from both developed and developing nations demonstrate a substantial correlation between prenatal exposure to ambient air pollution and the onset of Autism Spectrum Disorder (ASD), especially during the late second and third trimesters, which are pivotal periods for synaptic development and cortical maturation (Raz et al., 2015).

Studies globally have shown that extended exposure to $PM_{2.5}$ during pregnancy can hinder neuronal signaling, disturb neurotransmitter pathways, and modify synaptic plasticity, all of which are mechanisms linked to ASD. Similar biological mechanisms may be significant in Bangladesh, where constant exposure to increased air pollution levels becomes worse by socioeconomic stressors, including overcrowding, inadequate nutrition, and poor access to prenatal healthcare. In Bangladesh, air pollution has been significantly related to negative pregnancy outcomes, including preterm birth, low birth weight, and decreased cognitive development in children (Perera et al., 2019). These outcomes act as intermediary pathways through which air pollution may influence neurodevelopmental disorders, including ASD. Low birth weight and preterm birth are widely acknowledged as critical indicators of delayed cognitive development, behavioral issues, and social communication deficits, all of which are the core characteristics of ASD.

Furthermore, long-term exposure to black carbon and nitrogen dioxide causes systemic inflammation and modifies the expression of genes pertinent to fetal brain development. The inflammatory response triggered by air pollution may interfere with synaptic organization and neurotransmitter function during prenatal brain development, potentially heightening exposure to Autism Spectrum Disorder in later childhood (Raz et al., 2015). The issue is particularly significant in Bangladesh because of the mix of industrial emissions, unregulated brick kilns, heavy traffic, and serious development of cities. These environmental factors, along with maternal vulnerability, may significantly raise the risk of ASD in children.

Industrial Waste and Chemical Exposure

Bangladesh's rapid industrial expansion has contributed significantly to national economic development; however, it has simultaneously intensified environmental pollution, particularly in densely industrialized regions. Major industrial hubs such as Dhaka, Gazipur, Narayanganj, Chattogram, and Savar discharge substantial quantities of hazardous substances into surrounding air, soil, and water systems, creating serious public health concerns for pregnant women and developing fetuses (Niloy et al., 2025; Hossen et al., 2024). Common industrial contaminants include textile dyeing chemicals, organic solvents, and heavy metals such as lead, mercury, cadmium, and chromium, primarily released from textile dyeing factories, leather tanneries, metal workshops, and informal recycling facilities, including battery recycling units (Ali & Ahmed, 2025). Due to inadequate waste treatment infrastructure and weak enforcement of environmental regulations, these toxic substances frequently infiltrate groundwater, irrigation canals, drinking water supplies, and agricultural land (Niloy et al., 2025).

Pregnant women residing in close proximity to industrial clusters are at heightened risk of chronic exposure to neurotoxic chemicals through inhalation of polluted air, dermal contact, and ingestion of contaminated food and water (Hossen et al., 2024). Heavy metals such as lead and mercury are of particular concern, as they can cross the placental barrier and accumulate in fetal tissues during critical stages of neurodevelopment (Zhang et al., 2023). These toxicants interfere with essential neurodevelopmental processes, including neuronal migration, synapse formation, and neurotransmitter regulation (Modabbernia et al., 2024). Prolonged maternal exposure to mercury has been associated with impaired synaptic plasticity, cognitive dysfunction, and abnormal cortical development in offspring, thereby increasing the risk of neurodevelopmental disorders, including autism spectrum disorder (ASD) (Zhang et al., 2023).

Cadmium and chromium, commonly released from tannery effluents and metal processing activities, induce oxidative stress and epigenetic modifications that may alter prenatal brain programming (Ali & Ahmed, 2025). These toxic exposures can also disrupt placental function, reducing the transfer of oxygen and essential nutrients to the fetus, which is associated with low birth weight, preterm birth, and long-term neurodevelopmental impairments (Raqib et al., 2021). Additionally, textile dyeing industries release azo dyes, phenolic compounds, and volatile organic compounds that can disrupt cellular signaling and immune-regulatory pathways, potentially promoting neuroinflammatory mechanisms linked to ASD-related behaviors (Hossen et al., 2024; Modabbernia et al., 2024).

Women living in industrialized areas are often exposed to multiple overlapping environmental stressors, including air pollution, heavy metal contamination, noise exposure, and chronic psychosocial stress. The combined effect of these stressors further increases vulnerability to adverse pregnancy outcomes and neurodevelopmental disorders in children (Niloy et al., 2025). In the context of Bangladesh, where environmental monitoring and regulatory enforcement remain limited, pregnant women residing in industrial peripheries represent an under-recognized high-risk population in ASD-related research and public health surveillance (Modabbernia et al., 2024).

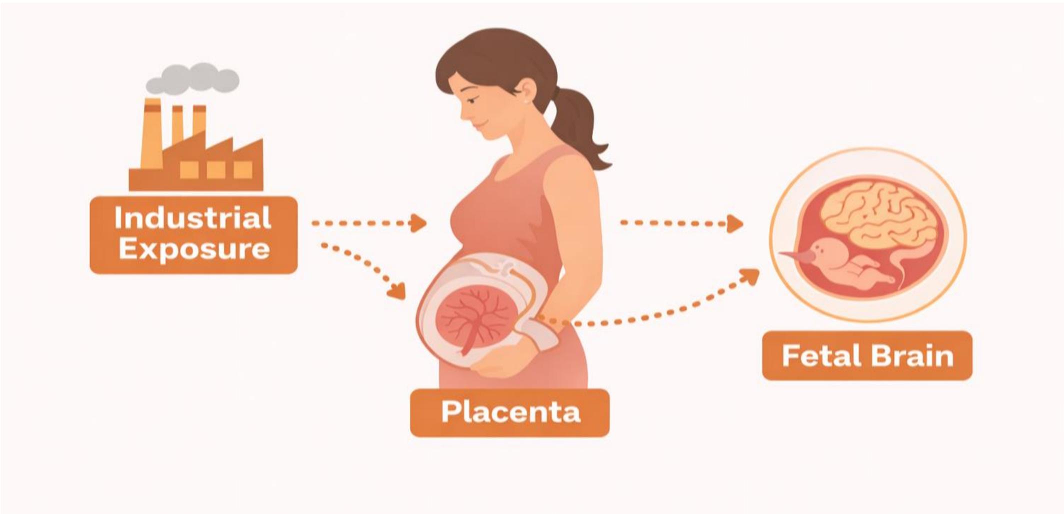

Figure 08: Mechanism of Industrial Exposure Affecting Neurodevelopment

Traffic Proximity and ASD Risk

In the urban regions of Dhaka and Chattogram, many residential areas are situated close to bustling highways, industrial routes, and congested intersections. These roads experience continuous vehicle movement, including trucks, buses, cars, and industrial transport carriers. As a result, the surrounding environment is frequently polluted with harmful substances such as particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), carbon monoxide (CO), and volatile organic compounds (VOCs). These pollutants are known to be hazardous to maternal and fetal health.

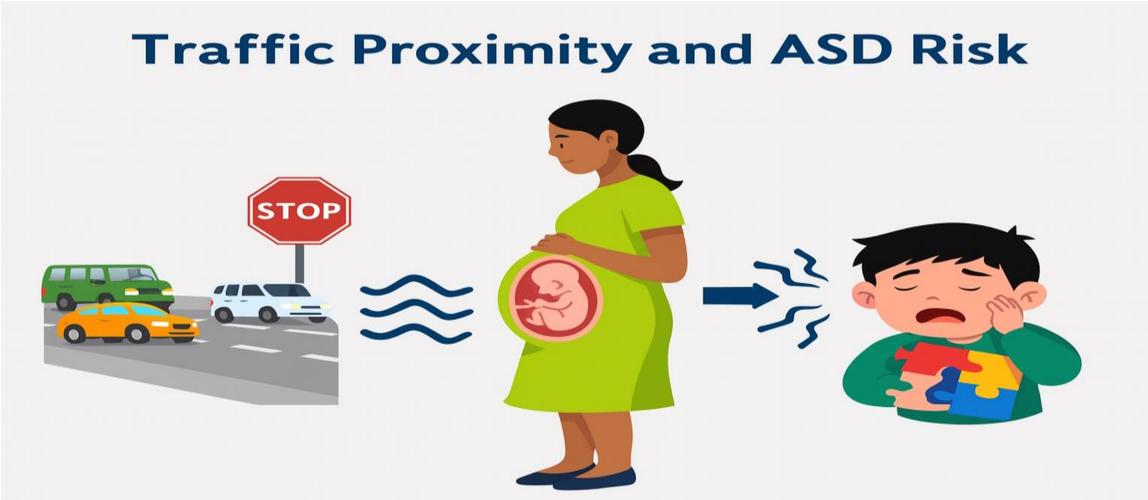

Figure 09: Impact of Traffic Emission Exposure on Prenatal Development and ASD Risk

Pregnant women living in high-traffic areas are at greater risk because fine air particles can enter the bloodstream, reach the placenta, and influence fetal brain development. Heavy-duty trucks that often run on diesel and release hazardous gases and heavy metals use manufacturing highways as well. These pollutants can induce oxidative stress, inflammation, and problems with the development of the neurological system in the unborn baby. Noise pollution from continuous traffic can also increase maternal stress, which may indirectly affect fetal neurodevelopment. A case–control research in Bangladesh demonstrated a strong correlation between maternal closeness to major roadways and the likelihood of Autism Spectrum Disorder (ASD) in offspring. The study shows that moms residing within a few kilometers of a major roadway during pregnancy had a higher likelihood of having children subsequently diagnosed with ASD (Hossain et al., 2022). This indicates that exposure to environmental contaminants from vehicular and industrial mobility may elevate the risk of neurodevelopmental problems. These results show that we need to build cities better, control industrial pollutants better, and teach pregnant women about the dangers of smoking. Making green buffers, cutting down on air pollution, and promoting better home planning could help keep mothers and children healthy (Hossain et al., 2022).

Indoor Air Pollution from Biomass Fuel and Mosquito Coils and Aerosol Sprays

Around 30% of rural Bangladeshi households still mainly rely mainly on Firewood, dung cakes, crop residues. kerosene stoves. Indoor smoke contains particulate matter, carbon monoxide, benzene, and formaldehyde, leading to maternal hypoxia and inflammation. Indoor smoke is linked with low birth weight and delayed brain development (Khan et al., 2019). Bangladesh has one of the highest rates of mosquito coil use in Asia. These products release pyrethroids and toxic smoke equivalent to 100 cigarettes per night. A case control study from Dhaka found significant associations between prenatal exposure to: mosquito coil smoke, insecticidal aerosols, room sprays increased ASD risk (Hossain et al., 2022).

Arsenic-Contaminated Drinking Water

Arsenic in groundwater has become a major public health problem, which puts millions of people at risk of long-term exposure to poison. Arsenic is well known to be a strong neurotoxin that can get through the placenta and build up in the tissues of the embryo. Extended maternal exposure during gestation can interfere with typical fetal brain development. Research shows that arsenic poisoning causes neurons to die, makes it harder for synapses to form, and raises oxidative stress in the developing brain (Rahman et al., 2017). These neurobiological alterations can hinder cognitive functioning and result in neurodevelopmental disorders in children. Pregnant women residing in arsenic-affected regions are especially susceptible due to the ongoing ingestion of contaminated tube-well water. Arsenic's neurotoxic effects can disrupt neural signaling, impede neurogenesis, and alter fetal brain structure, thereby elevating the risk of developmental disabilities. These interruptions may raise the risk of long-term cognitive deficits, learning problems, and behavioral disorders. It is very important to protect the health of mothers and children in areas where groundwater has high levels of arsenic. To lower the risk of neurodevelopmental problems caused by arsenic in Bangladesh, it is important to make sure that people have access to safe drinking water, raise awareness in the community, and put preventive health measures into place (Rahman et al., 2017).

5.3 Socioeconomic and Healthcare Barriers

Bangladesh faces multiple socioeconomic and cultural challenges that significantly influence maternal health, pregnancy outcomes, and fetal neurodevelopment. Emerging scientific evidence suggests that maternal factors such as inadequate prenatal care, chronic psychosocial stress, maternal malnutrition, adolescent pregnancy, and anemia may indirectly increase the risk of Autism Spectrum Disorder (ASD) by altering the intrauterine environment and disrupting normal fetal brain development (Gardener et al., 2009; Coussons-Read, 2013). These risk factors are particularly pronounced in low-resource settings, where limited access to quality healthcare services, poor nutritional status, low maternal education, and weak social support systems persist (WHO, 2016; Rahman et al., 2020). Chronic maternal stress and nutritional deficiencies during critical periods of gestation may lead to inflammation, hormonal dysregulation, and impaired neurodevelopmental processes, thereby increasing vulnerability to neurodevelopmental disorders such as ASD (Black et al., 2013; Brown et al., 2014).

Limited Antenatal Care Access

A substantial proportion of pregnant women in rural and peri-urban areas of Bangladesh lack adequate access to antenatal care (ANC). Many women do not complete the WHO-recommended minimum of four antenatal visits and therefore miss essential services such as hemoglobin assessment, iron–folic acid supplementation, nutritional counseling, and routine blood pressure monitoring (National Institute of Population Research and Training [NIPORT] et al., 2020). As a result, maternal conditions, including anemia, gestational hypertension, thyroid disorders, infections, and gestational diabetes, often remain undiagnosed and untreated. These conditions are known to adversely affect fetal brain development and may contribute to neurodevelopmental vulnerability, including pathways associated with autism spectrum disorder (ASD) (World Health Organization [WHO], 2016).

Iron and folic acid supplementation during pregnancy is critical for neural tube formation, myelination, synaptogenesis, and overall fetal brain growth. Maternal anemia remains highly prevalent in Bangladesh, affecting over 40% of pregnant women, and iron deficiency during gestation has been linked to impaired neuronal signaling and cognitive development in offspring (NIPORT et al., 2020). Furthermore, the absence of adequate nutritional counseling contributes to dietary deficiencies of key neurodevelopmental nutrients such as omega-3 fatty acids, iodine, choline, and vitamin D. Limited ANC coverage also reduces opportunities to educate mothers about environmental toxin exposure, safe medication use, infection prevention, and stress management. Consequently, pregnant women may remain exposed to harmful agents, including TORCH infections, which are associated with increased risks of adverse neurodevelopmental outcomes. Overall, inadequate antenatal care creates a suboptimal intrauterine environment that may elevate the risk of ASD and related developmental disorders.

Maternal Stress and Mental Health Challenges

Social and psychological stress is increasingly recognized as a critical factor influencing fetal growth and neurodevelopment. In Bangladesh, many pregnant women experience persistent stress due to financial insecurity, heavy domestic workloads, limited autonomy, family conflict, and inadequate emotional and social support. These stressors contribute to chronic anxiety and depressive symptoms during pregnancy. Maternal psychological stress affects fetal development through several biological mechanisms, particularly dysregulation of the hypothalamic–pituitary–adrenal (HPA) axis and increased production of stress hormones such as cortisol (Coussons-Read, 2013). Prolonged maternal stress results in elevated cortisol levels that can cross the placental barrier and enter the fetal circulation, potentially altering brain structure, synaptic formation, and neuronal differentiation. Sustained exposure to excess cortisol has been shown to impair hippocampal development, a brain region associated with learning, memory, emotional regulation, and social behavior domains commonly affected in Autism Spectrum Disorder (ASD) (Glover et al., 2018).

In addition to hormonal pathways, maternal stress induces inflammatory responses characterized by increased levels of pro-inflammatory cytokines, including interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), and interleukin-1β (IL-1β). Beversdorf et al. (2018) suggest that cytokine imbalance during gestation may disrupt neuroimmune interactions, leading to atypical microglial activation in the developing fetal brain. Microglia play a crucial role in synaptic pruning and neural circuit refinement, and disruption of these processes may result in abnormal neural connectivity, a well-documented feature of ASD. Maternal mental health problems also indirectly affect fetal development by reducing adherence to adequate nutrition, prenatal supplementation, timely healthcare utilization, and healthy sleep patterns. In Bangladesh, cultural stigma surrounding mental health often discourages pregnant women from seeking psychological support, resulting in untreated distress. Overall, maternal psychological well-being is a critical yet frequently overlooked determinant of fetal neurodevelopment and may contribute to increased vulnerability to ASD and related neurodevelopmental disorders.

Early Marriage and Teenage Pregnancy

In South Asia, Bangladesh has one of the highest rates of early marriage and pregnancy among teens. Teenage mothers are often not ready for pregnancy in terms of their bodies, their diets, or their mental health, which raises the risk of problems that could affect the development of the fetus. Teenage pregnancy often results in maternal malnutrition, as the mother's body competes with the fetus for vital nutrients required for her own physical development. In addition, not getting enough nutrients raises the chances of anemia, low birth weight, and intrauterine growth restriction (IUGR), all of which are important signs of future neurodevelopmental problems. Another big problem with getting married young is that it hurts your education. Teen mothers frequently exhibit reduced educational attainment, which is associated with insufficient understanding of prenatal care, nutrition, and maternal health practices. This makes it more likely that people will not go to enough ANC visits, will not stick to their supplement plans, and will use traditional remedies instead of going to the doctor. Young women who marry young or get pregnant as teenagers are also more likely to suffer emotional stress, have less power to make decisions, and sometimes be victims of domestic violence. Stress from these situations can cause the HPA axis to be active all the time, just like stress in adult mothers. This can raise cortisol levels, which can affect the development of the fetal brain (Beversdorf et al., 2018). Moreover, adolescent pregnancies are associated with increased rates of preterm birth and delivery complications, which may result in hypoxic conditions, metabolic distress, or neonatal infections, potentially exacerbating ASD-related vulnerabilities. In Bangladesh, limited access to antenatal care, maternal stress, and teenage pregnancy are all closely linked social factors that affect the health of mothers and the development of their babies' brains. These factors influence overall pregnancy outcomes and may also activate biological and environmental mechanisms that heighten susceptibility to ASD. To improve the health of mothers as well as kids, it is important to strengthen antenatal services, promote mental health support for mothers, and reduce early marriage through policy, education, and community awareness.

Chapter 6: Research Gaps and Future Directions

6.1 Identification of Key Research Gaps

Understanding prenatal determinants of Autism Spectrum Disorder (ASD) requires strong, multidisciplinary evidence that integrates biological, environmental, nutritional, and psychological perspectives. Worldwide, significant progress has been made in identifying how maternal conditions such as stress, nutrition, infections, endocrine disorders, and environmental toxic exposure influence fetal brain development. However, in Bangladesh, research on these determinants remains limited, fragmented, and often lacks methodological depth. Existing studies largely focus on clinical diagnosis and behavioral aspects of ASD rather than investigating prenatal risk pathways. These shortcomings have created significant research gaps that limit the country's ability to develop locally relevant ASD prevention and intervention strategies. This chapter examines major research gaps, identifies challenges in the existing literature, and proposes future directions to improve ASD research capacity in Bangladesh.

Gap 1: Limited Research on Prenatal Biological Pathways

Globally, prenatal determinants of ASD have been widely studied through biological mechanisms involving neuroinflammation, oxidative stress, hormonal imbalance, and immune dysregulation. Studies such as Beversdorf et al. (2018) have demonstrated how maternal stress and inflammation influence fetal brain development by affecting cytokine regulation and HPA-axis functioning. However, studies in Bangladesh rarely examine these biological mechanisms using laboratory-based assessments or biomarker analysis.

Most research in Bangladesh relies on descriptive approaches and self-reported questionnaires, lacking biological testing such as cortisol level measurement, iron biomarkers, thyroid tests, or inflammatory markers in pregnant women. As a result, it is not possible to determine whether maternal stress, anemia, or immune disorders directly contribute to ASD pathways. There is also limited use of neuroimaging or developmental neurobiology to examine the impact of prenatal stress or malnutrition on fetal brain structure. Without biological data, it becomes challenging to understand how prenatal exposures trigger neurodevelopmental disorders like ASD.

Gap 2: Inadequate Data on Maternal Stress and Mental Health

Maternal stress and depression are established risk factors for ASD through dysregulation of the HPA axis (Beversdorf et al., 2018). However, Bangladesh lacks comprehensive research investigating these psychosocial stressors during pregnancy. Existing studies focus mainly on postpartum depression, with little attention to antenatal stress, anxiety, or emotional abuse experienced by pregnant women.

Furthermore, research does not explore cultural and structural stressors such as financial hardship, domestic violence, household workload, early marriage, and limited social support that may influence maternal mental health. There is also a lack of tools adapted to the Bangladeshi context to measure stress biologically through cortisol or inflammatory cytokine analysis. Because of this gap, the stress-ASD connection remains unexplored in Bangladesh, despite strong global evidence.

Gap 3: Absence of Longitudinal and Cohort-Based Studies

Most studies in Bangladesh on child development and ASD are cross-sectional, meaning they only capture data at one point in time. This type of design cannot establish causal relationships between prenatal exposures and later ASD development. In contrast, global research uses longitudinal cohort studies that track pregnant women and follow their children for years, analyzing how prenatal exposures influence neurodevelopment.

Bangladesh has no large-scale birth cohort studies to examine prenatal influences on ASD risk. Without longitudinal tracking, it is difficult to determine how maternal diet, stress, environmental exposures, or infections during pregnancy contribute to ASD in children. Cohort studies would also help identify early warning signs, critical windows of risk, and potential preventive strategies. This research design gap significantly limits Bangladesh's ability to make evidence-based conclusions.

Gap 4: Limited Exploration of Environmental Toxins and Pollutants

Global evidence highlights that exposure to heavy metals such as lead, mercury, arsenic, and cadmium can negatively impact fetal neurodevelopment. However, research in Bangladesh rarely investigates these toxic exposures in relation to ASD. Bangladesh is one of the most arsenic-affected countries in the world, and thousands of households rely on contaminated groundwater. Yet, the relationship between arsenic in drinking water and fetal neurodevelopment is not widely studied in the Bangladeshi context.

Similarly, Bangladesh has high levels of air pollution from traffic emissions, brick kilns, textile factories, and tanneries. These sources release particulate matter (PM2.5), nitrogen dioxide (NO2), sulfur dioxide (SO2), and volatile organic compounds (VOCs), all of which have been linked to impaired neurodevelopment globally. However, there is a lack of local research investigating whether pregnant women's exposure to traffic or industrial areas increases ASD risk in their children.

While Beversdorf et al. (2018) emphasize the role of inflammation in ASD, Bangladesh-based studies do not examine whether environmental pollutants cause inflammatory responses that impact fetal brain development. This represents a significant research gap that must be addressed.

Gap 5: Lack of Focus on Maternal Nutrition and Lifestyle

Maternal nutrition is crucial for fetal brain development, especially nutrients such as folate, omega-3 fatty acids, iodine, iron, choline, and vitamin D. Global studies associate poor maternal nutrition with increased risk of neurodevelopmental disorders. However, research in Bangladesh often focuses on general maternal anemia or malnutrition rather than investigating specific nutrients linked to ASD pathways.

Furthermore, there is minimal attention given to lifestyle factors during pregnancy, such as physical activity, screen exposure, sleep patterns, or daily stress management. These lifestyle aspects strongly influence maternal hormonal balance, immune function, and mental health, all of which may contribute to neurodevelopmental vulnerability (Beversdorf et al., 2018).

Gap 6: Underrepresentation of Rural and Marginalized Populations

Most existing research in Bangladesh is conducted in major urban areas such as Dhaka and Chattogram. Rural and marginalized communities that face higher rates of malnutrition, poor healthcare access, untreated infections, and environmental exposure are significantly underrepresented in ASD research. Studies rarely address vulnerable groups such as tribal populations, climate-affected communities, tea workers, slum-dwellers, or those living near industrial zones.

Therefore, the existing research does not reflect population-wide prenatal risk factors. To build a nationally relevant understanding, future studies must include diverse geographic, socioeconomic, and cultural populations.

Gap 7: Lack of Integration Between Disciplines

ASD research requires collaboration between pediatrics, neurology, psychology, nutrition, public health, environmental science, genetics, and social sciences. However, most studies in Bangladesh are conducted from a single-discipline perspective. For example, medical researchers focus on clinical diagnosis while public health researchers focus on social risk factors. There is limited integration of biological testing, environmental exposure mapping, or biomarker-based research. Beversdorf et al. (2018) emphasize that ASD risk is influenced by psychological and biological interactions involving inflammatory cytokines, stress hormones, and neurodevelopmental processes. Without interdisciplinary collaboration, it is not possible to fully understand these complex mechanisms.

6.2 Gaps in Bangladeshi Research

A notable research gap in Bangladesh is the scarcity of high-quality studies investigating the association between prenatal nutrition and Autism Spectrum Disorder (ASD). While national surveys consistently document widespread micronutrient deficiencies among pregnant women, they do not extend their analysis to neurodevelopmental outcomes in children. Although global research demonstrates strong links between maternal nutritional biomarkers and ASD risk (Schmidt et al., 2019), no studies in Bangladesh have examined maternal serum levels of critical nutrients such as folate, ferritin, vitamin D, or omega-3 fatty acids with respect to ASD. This absence of biomarker-based research significantly limits the ability to determine whether maternal nutritional deficiencies directly contribute to neurodevelopmental impairments in Bangladeshi children.

Furthermore, most studies on maternal diet in Bangladesh rely on household food recall or general dietary questionnaires. These methods are highly susceptible to recall bias and measurement errors, particularly in rural settings where food access is seasonal, culturally influenced, and dependent on household economic conditions (Ahmed et al., 2020). The lack of precise dietary intake measurements prevents researchers from establishing specific associations between maternal nutrition, fetal brain development, and ASD outcomes. Consequently, Bangladesh remains without robust evidence linking maternal nutrition to neurodevelopmental disorders.

Another major gap is the absence of prospective birth cohort studies. Unlike high-income countries such as Norway and the United States, which maintain large longitudinal datasets tracking maternal exposures and child neurodevelopment over time, Bangladesh has no such population-based cohorts. The absence of these long-term studies prevents researchers from understanding the timing, duration, and combination effects of prenatal exposures that may contribute to ASD. Longitudinal designs are essential for assessing dose–response relationships, identifying critical exposure windows, and tracking developmental milestones across infancy and early childhood. In contrast, most existing Bangladeshi studies are cross-sectional or hospital-based case–control studies with small sample sizes, limiting their capacity to establish causal relationships or generalizable findings.

Environmental exposure research in Bangladesh is similarly inadequate. Despite having some of the highest levels of air pollution, pesticide use, and heavy metal contamination globally, very few studies have investigated how these exposures affect fetal neurodevelopment. Many environmental studies focus only on immediate birth outcomes such as prematurity, stillbirth, and low birth weight (Perera et al., 2019), while long-term neurodevelopmental consequences such as ASD are rarely explored. This gap is particularly alarming because Bangladesh is known for widespread arsenic contamination in groundwater, as well as lead- and mercury-tainted food supply chains (Jahan & Hossain, 2020). However, no studies have analyzed maternal or cord blood samples for heavy metal concentrations among children diagnosed with ASD in Bangladesh.

Indoor environmental exposures also remain underexplored. Common household exposures in Bangladesh, including mosquito coils, biomass fuel, incense smoke, and cooking emissions, have the potential to influence fetal neurodevelopment but are rarely measured systematically. Emerging research suggests that indoor air pollution may contribute to ASD risk, yet only one recent case–control study in Bangladesh has attempted to investigate this link (Hossain et al., 2022). This highlights a significant need for biomarker-based environmental research using biological sampling methods such as blood, urine, or hair to measure cumulative toxic exposure during pregnancy.

Research on maternal lifestyle and psychosocial factors is also significantly underdeveloped. Globally, maternal stress, depression, anxiety, sleep disturbances, and low physical activity during pregnancy are recognized contributors to neurodevelopmental vulnerabilities, including ASD (Beversdorf et al., 2018). However, Bangladeshi research seldom incorporates validated psychological assessment tools or biochemical measurements of stress (e.g., cortisol levels or inflammatory cytokines). Most studies rely on self-reported stress, which does not capture physiological responses that may influence fetal brain development. This is particularly concerning given that Bangladeshi women frequently experience economic strain, heavy domestic workloads, marital stress, and social limitations, all of which may affect maternal mental health and pregnancy outcomes.

Socioeconomic and cultural influences also remain understudied in ASD research in Bangladesh. The country's unique demographic conditions, including high rates of early marriage, large household sizes, food insecurity, cultural food taboos during pregnancy, and dependence on traditional healthcare practices, can significantly shape maternal diet, stress levels, and prenatal care utilization. Yet, very few studies integrate socioeconomic, dietary, psychological, and environmental factors into a single analytical framework. The lack of multidisciplinary and multifactorial analysis prevents researchers from identifying clusters of risk factors that may disproportionately affect certain populations, such as rural families, low-income groups, adolescents, and women with limited autonomy.

Another major limitation is the challenge of diagnosis and reporting of ASD in Bangladesh. National-level standardized screening programs for early ASD detection are lacking, and diagnosis often occurs late, typically between ages four and six, especially in rural and underserved communities (Zaman et al., 2021). This delay leads to underdiagnoses and underreporting, meaning that existing ASD datasets underestimate true prevalence and are not representative of the wider population. Most available research samples are drawn from urban clinics and special-needs schools, which exclude large populations of undiagnosed children, particularly in rural and low-resource areas.

Moreover, Bangladesh lacks centralized databases to track maternal health conditions, environmental exposure history, or child developmental outcomes. The absence of integrated digital surveillance systems hinders researchers from establishing connections between prenatal exposures and long-term child health outcomes. Without reliable, population-level data, it remains difficult to design large-scale epidemiological studies that can evaluate ASD in relation to maternal health, lifestyle, or environmental risk patterns.

Finally, there is a lack of interdisciplinary research exploration. While ASD is influenced by complex interactions between genetic, environmental, nutritional, and psychological factors, most studies in Bangladesh operate within single disciplines, such as pediatrics, psychology, or nutrition, without cross-disciplinary collaboration. Beversdorf et al. (2018) highlight that ASD risk is shaped through inflammatory and neuroendocrine pathways influenced by maternal stress and immune responses. However, Bangladeshi studies seldom integrate biological, clinical, environmental, and psychological data to examine these interconnected mechanisms.

6.3 Public Health Implications

1. Strengthen Longitudinal and Cohort-Based Research

Bangladesh should establish maternal-child cohort studies to examine how prenatal exposures influence neurodevelopment across the first 5–10 years of life. This design allows for tracking maternal stress, nutrition, infections, and environmental exposures and linking them with ASD outcomes (Ozonoff et al., 2018; Hertz-Picciotto et al., 2018; World Health Organization [WHO], 2016; Lyall et al., 2017).

2. Develop Maternal Neurodevelopmental Exposure Registries

There is a need for national databases to record prenatal exposure to nutritional, psychological, and environmental risk factors. These systems can store data on maternal diet, stress levels, toxic exposure, and health conditions, helping researchers identify potential ASD risk patterns (World Health Organization [WHO], 2016; Lyall et al., 2017; Grandjean & Landrigan, 2014; Sandin et al., 2017).

3. Integrate Biomarker-Based Approaches

Future studies should analyze biomarkers such as cortisol (for stress), C-reactive protein (for inflammation), ferritin (for anemia), thyroid hormone (for endocrine disorders), and cytokines (related to immune dysregulation). This would allow researchers in Bangladesh to build biologically grounded evidence similar to international ASD research (Beversdorf et al., 2018).

4. Build Multidisciplinary Research Teams

Researchers from nutrition, obstetrics, psychology, pediatrics, neurology, genetics, and environmental health should collaborate to examine how different prenatal factors interact and affect ASD outcomes (Lyall et al., 2017; Volk et al., 2014; Hertz-Picciotto et al., 2018; Rutter et al., 2019).

5. Include Rural and Marginalized Communities

Future research must expand beyond urban centers and include populations from climate-vulnerable, industrial, slum, and remote village areas to capture the real diversity of Bangladesh's environmental and social challenges.

6. Encourage Government and Policy Support

Public health authorities and policymakers should establish maternal stress screening, environmental monitoring, neurodevelopmental clinics, and autism surveillance systems. These initiatives can help track maternal health risks and support early intervention strategies.

7. Promote Awareness and Community-Based Research

Community-based programs should educate women about the importance of mental health care, nutrition, antenatal visits, and environmental safety during pregnancy. Researchers should include pregnant women, health workers, and families in participatory studies. Bangladesh has made notable progress in ASD awareness and diagnosis, yet substantial research gaps limit its ability to understand prenatal determinants of autism. Current studies lack biological evidence, longitudinal data, environmental exposure analysis, and multidisciplinary integration. Strengthening research methodologies, promoting collaboration, and investing in maternal health surveillance will help build a stronger scientific foundation for ASD prevention and early intervention. As Beversdorf et al. (2018) emphasized, understanding maternal stress, inflammation, and neurodevelopmental mechanisms is essential, and Bangladesh must now adapt this knowledge to its local context.

Limited Use of Advanced Tools and Multidisciplinary Approaches

ASD is influenced by interactions between genetic predisposition, immune activation, maternal stress, metabolic disorder, and environmental toxins (Beversdorf et al., 2018). Yet, most studies in Bangladesh adopt single-variable models and do not incorporate gene–environment interactions, neuroinflammatory pathways, or biomarker testing.

Global research increasingly uses advanced methods such as:

Method	**Purpose in ASD Research**
Neuroimaging (fMRI, DTI)	Detect structural brain changes
Cytokine and cortisol assays	Measure inflammation and stress
Geographic exposure mapping	Track prenatal pollutant exposure
Epigenetic analysis	Study DNA methylation and gene expression
Wearable stress monitors	Track maternal psychosocial risk

Table 06: Research Methods and Their Applications in Autism Spectrum Disorder (ASD) Studies

Bangladeshi studies seldom apply these approaches, leading to a very limited understanding of underlying neurobiological mechanisms.

Despite growing awareness of ASD in Bangladesh, major research gaps persist—particularly in areas relating to prenatal nutrition, environmental toxicity, maternal stress physiology, and longitudinal study designs. Methodological limitations, lack of biomarker-based studies, and absence of integrated datasets further constrain the ability to understand how prenatal exposures may contribute to ASD risk. Addressing these gaps will require multidisciplinary collaboration, improved diagnostic infrastructure, national cohort development, and stronger maternal health surveillance across the country (Lyall et al., 2017; Hertz-Picciotto et al., 2018; Grandjean & Landrigan, 2014; World Health Organization [WHO], 2016; Sandin et al., 2017).

6.4 Recommendations for Future Studies

To address the existing research gaps and methodological limitations in understanding Autism Spectrum Disorder (ASD) in Bangladesh, it is essential to reorient scientific efforts towards more systematic, data-driven, and multidisciplinary research approaches. While global studies have advanced through longitudinal cohort designs, biomarker assessments, environmental exposure mapping, and sophisticated neurodevelopmental analysis, research in Bangladesh remains largely descriptive and fragmented. The following recommendations aim to guide future research directions, ensuring methodological rigor, contextual relevance, and scientific validity in studying prenatal determinants of ASD. One of the most fundamental recommendations is the establishment of large-scale prospective birth cohort studies across different regions of Bangladesh. Unlike cross-sectional or case–control studies, prospective cohort designs allow researchers to trace maternal exposures during pregnancy and assess developmental outcomes in children over several years. Such studies help build temporal and causal relationships, enabling the observation of how risk exposures accumulate or interact at various stages of fetal brain development. The cohort should include pregnant women from diverse socioeconomic, geographic, and cultural backgrounds, including urban, rural, industrial, coastal, and low-income communities. This would provide valuable insights into how exposure to pollutants, nutritional deficiencies, early marriage, maternal stress, or inadequate antenatal care varies among populations and influences ASD outcomes.

These cohort studies should collect biological samples such as blood, saliva, urine, hair, and cord blood at different stages of pregnancy. Such biological data would allow analysis of biomarkers linked to maternal nutrition (folate, vitamin D, omega-3 fatty acids, and ferritin), immune activation (cytokines), hormonal balance (cortisol), and toxic exposure (arsenic, lead, mercury). By moving beyond self-reported dietary data, future studies can incorporate reliable biomarker-based evidence that enhances scientific validity (Schmidt et al., 2019; Ahmed et al., 2020).

Integration of Nutritional Biomarker Analysis into ASD Risk Research

Bangladesh must move beyond the use of dietary recall methods, which are susceptible to memory bias, seasonal variation, and inaccurate reporting, especially in low-literacy rural settings (Ahmed et al., 2020). Instead, maternal serum biomarkers should be used to objectively measure micronutrient levels during pregnancy.

Biomarker	**Significance for Brain Development**
Folate	Neural tube formation, methylation
Vitamin D	Neuroprotection, synaptic signaling
Ferritin	Myelination and oxygen supply
Omega-3 fatty acids	Neuronal connectivity & membrane stability

Table 07: Key Maternal Nutritional Biomarkers and Their Roles in Fetal Brain Development

Testing these biomarkers in maternal, cord blood, and neonatal samples would allow researchers to assess whether persistent nutritional deficiencies correlate with ASD risk. Additionally, repeated sampling across different trimesters would help in identifying the critical windows of vulnerability for brain development. Maternal dietary habits should also be studied in context, considering barriers such as cultural food restrictions, gender-biased food distribution, financial constraints, and poor access to antenatal Expansion of Environmental Exposure Research. Bangladesh faces severe environmental threats, including traffic-related air pollution, industrial emissions, pesticide contamination, heavy metal exposure, and indoor pollution from mosquito coils, biomass fuel, and poor ventilation. However, research linking these exposures to ASD remains extremely limited.

Future studies should be incorporated:

1. **Personal air quality sensors** to measure real-time exposure to PM2.5, PM10, NO_2, ozone, and VOCs.
2. **Geospatial mapping from satellite data** to identify pollution hotspots, industrial zones, and major transportation routes.
3. **Biological sample testing**, including hair, blood, and urine, to assess accumulated exposure to arsenic, mercury, lead, and pesticide residues.
4. **Cord blood analysis** to determine fetal exposure.

Such a multimodal environmental assessment, combining laboratory analysis and exposure modeling that can help explain how pollutants interact with fetal neurodevelopment. In addition, integrating these toxic exposures with stress or nutritional deficiencies could reveal synergistic effects using a "multiple risk exposure" framework. Strengthening Research on Maternal Mental Health and Stress Physiology Maternal stress, depression, and anxiety are emerging global risk factors for ASD through HPA-axis dysregulation and cytokine-mediated immune activation (Beversdorf et al., 2018). However, research in Bangladesh remains limited to basic psychological questionnaires, lacking physiological measurements of stress.

Measure	**Purpose**
Perceived Stress Scale (PSS)	Self-reported stress perception
Edinburgh Postnatal Depression Scale (EPDS)	Screening for depression
GAD-7	Anxiety screening
Pittsburgh Sleep Quality Index (PSQI)	Sleep pattern assessment
Cortisol (serum/salivary)	Biological stress marker
C-reactive protein, IL-6, TNF-α	Immune-inflammatory stress markers

Table 08: Instruments and Biomarkers for Evaluating Stress and Related Outcomes

Collecting both psychological and biological stress measurements would allow researchers to examine whether maternal stress leads to physiological inflammation, thereby affecting fetal brain development and potentially increasing ASD vulnerability.

Considering that Bangladeshi women often face economic hardship, heavy household workload, food insecurity, and limited social support, mental health variables must be considered essential, not optional components of ASD research.

Bangladesh's cultural context, including early marriage, gender norms, food taboos, and limited decision-making power for women, significantly influences maternal nutrition, healthcare access, and stress levels during pregnancy. Understanding ASD risk in Bangladesh requires integrating socioeconomic realities rather than importing Western theoretical assumptions.

Key elements for future research should include:

- Maternal autonomy in food choices and medical decisions (Mistry et al., 2009; WHO, 2016)
- Cultural food taboos during pregnancy (e.g., avoiding fish, eggs) (Gittelsohn et al., 1997; Ahmed et al., 2020)
- Seasonal food insecurity and household-level resource distribution (FAO, IFAD, UNICEF, WFP, & WHO, 2019; Rahman et al., 2018)
- Maternal workload and caregiving burden (Worku et al., 2013; WHO, 2016)
- Financial barriers to accessing antenatal supplements (Bhutta et al., 2013; BDHS, 2018)

By integrating these contextual factors into ASD risk analysis, researchers can generate culturally informed and locally relevant findings (Lyall et al., 2017; Hertz-Picciotto et al., 2018).

Improve Nationwide ASD Screening and Diagnostic Infrastructure

Early diagnosis of ASD is essential for both research and clinical intervention. However, delayed or incorrect diagnosis, which is common in Bangladesh, leads to underreporting and biased samples, making it difficult to study ASD prevalence or correlate it with prenatal determinants.

To improve diagnostic accuracy, Bangladesh should implement:

- Use of standardized screening tools**,** such as M-CHAT, ADOS-2, and CARS-2, in hospitals, schools, and community health centers. (Robins et al., 2014; Lord et al., 2012; Schopler et al., 2010).
- Training programs for child psychologists, pediatricians, school teachers, maternal health workers on early ASD detection.
- Digital ASD registry to track diagnostic trends, severity levels, and sociodemographic patterns.
- Integration with vaccination, nutrition, and school health records for early identification.

If diagnosis becomes more systematic and accessible, data accuracy will improve, enabling better research quality and public health planning (Hertz-Picciotto et al., 2018; Lyall et al., 2017).

Promote Interdisciplinary and Collaborative Research

ASD research requires integration of neuroscience, public health, obstetrics, nutrition, environmental science, psychology, and data science. However, Bangladeshi research typically operates within discipline-specific frameworks and rarely incorporates interdisciplinary approaches (Lyall et al., 2017; Hertz-Picciotto et al., 2018; Volk et al., 2014).

To advance research capacity, collaborations should be encouraged between:

Discipline	**Contribution to ASD Research**
Nutrition	Maternal diet and micronutrient analysis (Bhutta et al., 2013; Black et al., 2013)
Obstetrics	Prenatal health monitoring
Neuroscience	Developmental brain studies (Stiles & Jernigan, 2010)
Psychology	Stress and behavioral evaluations
Environmental science	Pollution exposure tracking (Grandjean & Landrigan, 2014)
Data science	Modeling risk patterns

Table 09: Multidisciplinary Approaches to Autism Spectrum Disorder Research

Partnerships between universities, hospitals, research laboratories, and government health agencies will help build comprehensive ASD research capacity. Future research must use rigorous methodological techniques, including longitudinal cohort designs, biomarker analysis, environmental exposure assessments, and validated mental health screening methods, to comprehend how prenatal variables impact ASD development in Bangladesh. Research on the biological, physiological, psychological, cultural, and socioeconomic factors influencing child neurodevelopment must go beyond clinical or behavioral observations.

Chapter 7: Discussion

7.1 Summary of Findings

Understanding Autism Spectrum Disorder (ASD) through the lens of prenatal influences requires a multidimensional perspective that considers biological, nutritional, environmental, psychosocial, and sociocultural determinants. To fully understand Autism Spectrum Disorder (ASD) through an understanding of prenatal impacts necessitates a comprehensive strategy that includes biological, nutritional, environmental, psychological, and sociocultural factors. The chapters before have shown that ASD is not linked to a unique factor; instead, it results from complex and dynamic interactions of various prenatal exposures that influence fetal neurodevelopment. Global research has greatly improved our understanding of these risk pathways, but the situation in Bangladesh is different because of the particular maternal health risks, environmental exposures, and social and economic circumstances that need to be taken into account when analyzing the results. This discussion incorporates worldwide evidence with studies from Bangladesh to show how local risk patterns fit with or do not fit with current neurological development models. It also looks at how this affects public health, maternal care, research, and policy development in Bangladesh.

Globally, prenatal micronutrient deficiencies have been considered a significant factor influencing fetal brain development. Folate, iron, vitamin D, and omega-3 fatty acids are crucial for the creation of myelin, synaptic signaling, DNA methylation, the development of the neural tube, and the migration of neurons (Lyall et al., 2017). A lack of any of these nutrients at important times of pregnancy may tangle up how neurons connect and make the brain more vulnerable to developmental problems. While global research identifies excessive maternal caloric intake or metabolic disorders as risk factors for ASD, the Bangladeshi context overwhelmingly highlights undernutrition, anemia, and restricted dietary diversity, particularly among rural and low-income women (Ahmed et al., 2020). This difference shows that in low-income areas, the risk factors for ASD are more directly linked to not getting enough nutrients than to eating too much. Also, cultural dietary taboos, gender-based food distribution, and money problems make it much harder for mothers to get the nutrients they need. This suggests that the nutritional factors that cause ASD in Bangladesh are closely linked to the country's socioeconomic situation.

Environmental exposures are a significant risk category identified in ASD research. Global data indicate that pollutants, including particulate matter (PM2.5 and PM10), nitrogen dioxide, heavy metals (mercury, arsenic, lead), and pesticide residues, may cause oxidative stress, inflammation, and epigenetic modification in the developing fetal brain (Modabbernia et al., 2017). Exposure to these toxicants before birth has been demonstrated to influence neurotransmitter modulation, synaptic development, and the thickness of the cortex. In Bangladesh, the intensity and duration of these exposures are frequently elevated due to unregulated industrial operations, emissions from brick kilns, heavy traffic, extensive pesticide application, biomass combustion, and indoor inhalants like mosquito coils (Perera et al., 2019). Groundwater arsenic exposure presents a distinct neurodevelopmental risk in Bangladesh, as millions daily ingest arsenic-contaminated water. These environmental dangers cause cumulative exposure effects, and pregnant women in high-risk areas have a higher toxic burden than those in many high-income countries. The connection of global research with local conditions suggests that environmental neurotoxic risk in Bangladesh may significantly influence ASD vulnerability, attributable to both heightened exposure levels and inadequate preventative measures.

Psychosocial and emotional stress during pregnancy is another important but largely ignored cause of ASD. Studies demonstrate that maternal stress can modify embryonic neurodevelopment via hypothalamic–pituitary–adrenal (HPA) axis dysregulation and altered cytokine signaling, potentially resulting in enduring behavioral and cognitive effects (Beversdorf et al., 2018). Countries with higher incomes often talk about stress caused by work, being alone, or health problems. Bangladeshi women, on the other hand, often have to deal with a lot of work at home, money problems, not having enough freedom, getting married young, not being able to make decisions, and sometimes being emotionally neglected or abused by their partners. These constant and cumulative stresses may exert a more significant physiological effect during gestation. However, in contrast to worldwide studies that utilize salivary cortisol, C-reactive protein, or cytokine analysis to investigate stress biology, Bangladeshi studies predominantly depend on self-reported questionnaires. This restricts the capacity to evaluate physiological stress pathways or measure their impact on ASD risk. The psychological aspect of ASD research in Bangladesh is still largely unexamined, even though it aligns well with studies from around the world.

Lifestyle factors during pregnancy contribute to this multifaceted risk profile. Global research emphasizes that maternal obesity, a sedentary lifestyle, insufficient physical activity, sleep difficulties, and poor mental health may affect fetal brain development via pathways of inflammation. In Bangladesh, lifestyle factors show up in numerous ways. Instead of being overweight and not getting enough exercise, many pregnant women are physically tired because they have a lot of cooking and cleaning to do, do not get enough rest, sleep poorly, and do not have easy access to maternal counseling. These circumstances, along with inadequate antenatal care, may elevate stress-induced inflammatory responses, therefore raising the risk of ASD in ways that differ from high-income environments (Beversdorf et al., 2018). The absence of community-based prenatal mental health services exacerbates these issues.

A significant finding from this study is that ASD-related risk patterns in Bangladesh do not only mirror global trends; instead, they underscore a convergence of many vulnerabilities, including dietary deficiencies, environmental toxicity, psychosocial challenges, and restricted healthcare access. This indicates the necessity for a tailored integrated risk model for low-income contexts, rather than depending exclusively on Western research paradigms. Bangladesh's distinctive exposure profile characterized by arsenic-contaminated drinking water, mosquito coil emissions, brick kiln smoke, pesticide-laden agricultural settings, and indoor biomass burning designates it as a high-risk ecological zone for fetal neurodevelopment, corroborating findings from both international and domestic studies (Hossain et al., 2022). However, local investigations infrequently elucidate these exposure pathways using biomarker analysis or spatial mapping.

These results have important effects on public health and policy. First, we need to enhance prenatal nutrition by making diets more varied, adding micronutrients, screening for anemia, and changing how we talk about behavior. Because there is a known link between folate, iron, vitamin D, and fetal brain development, adding routine biomarker testing to antenatal care should help find deficits early (Ahmed et al., 2020). However, success hinges on the resolution of structural impediments, including socioeconomic disparities, maternal displacement, and gender norms that influence nutritional accessibility.

Changes in environmental policy are just as essential. Bangladesh has to make rules about urban air pollution, keep an eye on emissions from brick kilns and manufacturers, control the use of pesticides, and encourage the use of clean cooking fuels to make the air inside homes better. At the household level, actions including using fewer mosquito coils, improving ventilation, and installing water filter devices in areas where arsenic is common could lower the risk of exposure to harmful chemicals during pregnancy. Environmental monitoring methods, such as geospatial pollution mapping, personal air quality sensors, and groundwater quality audits, may link epidemiological research to public health policy (Perera et al., 2019).

Maternal mental health requires immediate integration into prenatal services. There is a lot of research from throughout the world that shows a strong link between prenatal stress, cytokine imbalance, and the risk of ASD. However, stress screening is not common in regular care in Bangladesh (Beversdorf et al., 2018). Antenatal programs should incorporate validated psychological instruments such as the EPDS, PSS, and GAD-7, in addition to community-based counseling, peer support, and referral services. Family counseling that helps with a mother's workload, lack of sleep, and emotional health could lower the risks of long-term development.

Another important area is diagnostic surveillance. ASD is still not identified enough in Bangladesh because people do not know about it, there is a stigma around it, there are not enough specialists, and services are not evenly spread out. Most diagnoses happen late, usually after age five, when there are not as many possibilities for early intervention. Using standardized techniques like M-CHAT, ADOS-2, and CARS-2 in regular pediatric and community health care could help find problems earlier. Training teachers, community volunteers, and workers on the front lines would help much more with finding and sending people to the right place. Establishing a national ASD registry would help keep an eye on trends, find areas with a lot of risk, and make it easier to do big research projects.

According to theory, this study illustrates that ASD research in Bangladesh has to transition from fragmented symptom-focused methodologies to cohesive frameworks that incorporate biological, psychological, environmental, and cultural dimensions. The convergence of global and local evidence indicates that biological mechanisms such as oxidative stress, immune activation, and neurotransmitter dysregulation are universally pertinent; however, their triggers in Bangladesh are influenced by poverty, pollution, social practices, and systemic inequities. Knowing this context-specific complexity is crucial for designing treatment strategies that are both locally helpful and confirmed by research.

Lastly, the debate indicates that Bangladesh exhibits a distinctive array of ASD risk variables that correspond with worldwide models but necessitate regionally tailored interpretations. The presence of dietary deficiencies, environmental pollutants, psychosocial stress, and inadequate maternal care infrastructure influences prenatal vulnerability in distinct ways compared to high-income contexts. Consequently, policymakers and researchers must implement a comprehensive, culturally sensitive, and physiologically informed strategy for the prevention, surveillance, and early intervention of ASD in Bangladesh.

7.2 Limitations

This review is subject to several limitations that reflect both methodological constraints and broader challenges within ASD research in Bangladesh. This review has a few problems that are caused by both methodological issues and bigger problems with ASD research in Bangladesh. One of the biggest problems is that there are not enough long-term and prospective cohort studies that can track pregnancies over time and find links between certain prenatal exposures and ASD outcomes. The majority of research conducted in Bangladesh depends on cross-sectional, case–control, or clinical sample designs, which are limited to establishing connections rather than causal relationships. Without longitudinal follow-up or exposure tracking, it is challenging to ascertain whether identified risk aspects—such as malnutrition, stress, or exposure to pollutants—precede or result from ASD-related outcomes. These studies are additionally influenced by factors that confuse, including genetic predisposition, socioeconomic status, and environmental fluctuations, which are rarely sufficiently controlled.

Consequently, a significant portion of the current research lacks the methodological rigor required to substantiate robust causal findings.

Another significant disadvantage pertains to sampling and population representation. Most of the studies on ASD in Bangladesh take place in hospitals, private autism institutions, or larger clinical settings. These samples do not fully reflect the wider national population, especially in underserved and rural communities, where undernutrition, restricted healthcare access, environmental pollution, and maternal stress are more common. Many children with ASD in rural regions are still undiagnosed or misdiagnosed because people do not know much about it, and there is a stigma around it. This means that estimates of how common it is are probably too low. Additionally, the majority of studies exclude people who are marginalized, including slum residents, ethnic minorities, and communities situated in industrial or ecologically hazardous areas, resulting in substantial deficiencies in representativeness. This hampers the capacity to generalize findings and design customized interventions for various Bangladeshi communities.

Another big problem is the limits of diagnosis. Unfortunately, Bangladesh does not have standard nationwide ASD screening programs, and most diagnoses happen late, usually after children turn 4 to 6 years old. This is because of cultural stigma, lack of awareness, and not enough qualified specialists (Hossain et al., 2017; Durkin et al., 2015; World Health Organization [WHO], 2019). There are not enough psychologists, pediatric neurologists, and behavioral assessment professionals who know how to apply approved diagnostic methods like ADOS-2, M-CHAT, or CARS-2. In numerous instances, diagnosis depends on subjective parental accounts or informal behavioral assessments instead of established and standardized diagnostic tools (Lord et al., 2012; Robins et al., 2014; Schopler et al., 2010; Zwaigenbaum et al., 2015). This makes it less likely that the diagnosis is correct and more likely that the person will be misclassified, especially for milder forms of ASD (Mandell et al., 2009; Bishop et al., 2016). Also, lapses in diagnosis hinder the correlation of prenatal events or exposures with subsequent ASD-related outcomes, as recollection accuracy is diminished, and early developmental milestones are inadequately recorded (Hertz-Picciotto et al., 2018; Lyall et al., 2017).

The drawbacks of nutritional assessments reduce the credibility of current research in Bangladesh. The majority of research depends on dietary recall surveys, food frequency questionnaires, or household-level consumption reporting, all of which are susceptible to recall bias, errors, and inconsistencies. These approaches are unable to ascertain the bioavailability of micronutrients or precisely determine the consumption levels of essential nutrients, including folate, vitamin D, iron, and omega-3 fatty acids. Biochemical evaluations, like the measurement of serum ferritin, omega-3, or levels of homocysteine, are infrequently employed due to economic, infrastructural, and technical limitations. This makes it harder to appropriately look at nutritional inadequacies as possible risk factors. Seasonal changes in food availability, cultural dietary limitations, and gender-based food distribution patterns also make it harder to get accurate nutritional evaluations in Bangladesh.

There are also some big problems with environmental risk assessment. There is a lot of evidence that people in Bangladesh are exposed to pollutants such as arsenic, lead, mercury, pesticides, and traffic pollution. However, research on ASD rarely uses biomarker-based exposure testing with blood, urine, hair, or cord samples. Most studies use indirect methods, including being close to industrial areas or saying they were exposed, which do not give accurate estimations of real prenatal hazardous exposure. Indoor pollution evaluation is especially overlooked, even though mosquito coils, biomass fuel, incense, and kitchens that are not well ventilated are all common sources of neurotoxic chemicals. Furthermore, there is little integration between environmental exposure data and maternal inflammatory markers, complicating the comprehension of the molecular mechanisms by which contaminants influence fetal brain development.

There is also not enough research on psychosocial and behavioral conditions that affect mothers. Global literature underscores the impact of maternal stress, depression, anxiety, sleep deprivation, and physical activity on fetal brain development; nevertheless, these factors are hardly assessed with approved instruments in Bangladesh. A majority of research utilize unstructured interviews instead of standardized measures like the Edinburgh Postnatal Depression Scale (EPDS), Perceived Stress Scale (PSS), or Generalized Anxiety Disorder Scale (GAD-7). Moreover, there has been no ASD-related research in Bangladesh that investigates biological stress markers such as cortisol or pro-inflammatory cytokines (IL-6, TNF-α), despite their significant relevance to neurodevelopment. This results in a significant deficiency in comprehending how maternal stress physiology may influence ASD risk (Talge et al., 2007; Van den Bergh et al., 2017; Monk et al., 2019; Cox et al., 1987; Cohen et al., 1983; Spitzer et al., 2006; Brown et al., 2004; Lyall et al., 2017).

Another drawback is the absence of cohesive analytical models that investigate the interplay of dietary, environmental, psychological, and socioeconomic factors in affecting ASD vulnerability. Current research predominantly analyzes individual risk factors in isolation, rather than employing multidisciplinary frameworks that evaluate the cumulative effects of many exposures on fetal development. For instance, the interplay between nutritional insufficiency and arsenic exposure, or between maternal stress and inflammation, has yet to be investigated within the Bangladeshi setting. These intricate connections are inadequately comprehended in the absence of sophisticated statistical approaches such as structural equation modeling (SEM), multilevel analysis, or gene–environment interaction modeling *(Volk et al., 2014; Grandjean & Landrigan, 2014; Hertz-Picciotto et al., 2018; Sandin et al., 2017).*

Lastly, another problem is that the results of the global study may not be useful in Bangladesh. Global evidence can help us relate to abstract ideas better, but using it directly without adapting it to the culture or context may lead to wrong or useless conclusions. A lot of the risk factors that are important in high-income countries, like being overweight, not getting enough exercise, eating too many calories, and being older when you give birth, may not apply to most Bangladeshi women. These women are malnourished, work hard, and do not get enough prenatal care. In Bangladesh, on the other hand, industrial pollution, unregulated pesticide usage, and contaminated groundwater make environmental exposure patterns very different from those in the West. These contextual distinctions necessitate the creation of locally validated ASD risk models for Bangladesh, rather than relying exclusively on international evidence (Walker et al., 2011; Black et al., 2013; Ahmed et al., 2020; Rahman et al., 2018; WHO, 2016; Grandjean & Landrigan, 2014).

7.3 Proposed Solutions

In order to resolve the problems found in current research and ASD risk management in Bangladesh, we need a thorough, interdisciplinary, and context-specific approach that includes scientific research, public health policy, clinical practice, environmental safety, and maternal well-being. The primary objective is to initiate extensive, longitudinal birth cohort studies that monitor pregnant women and their offspring over time. Cohort designs, in contrast to cross-sectional or clinic-based research, facilitate the evaluation of temporal and causal links, and give researchers the opportunity to gather biological samples, track exposure patterns, and investigate neurodevelopmental outcomes through standardized instruments (Modabbernia, Velthorst, & Reichenberg, 2017; Lyall et al., 2017)

These investigations ought to include biomarker assessments for essential nutrients, such as folate, vitamin D, ferritin, and omega-3 fatty acids, with toxicological indicators including arsenic, mercury, lead, and pesticide residues. Collecting maternal blood, cord blood, and hair or urine samples at various stages of pregnancy would yield actual data on exposure levels and biological susceptibilities, rather than relying on self-reported information (Lyall et al., 2017; Christensen et al., 2016).

Improving the accuracy of measurements for dietary shortages and hazardous exposures also requires strengthening laboratory capabilities. To support micronutrient testing, cytokine analysis, hormonal assessments (such as cortisol to evaluate stress), and heavy metal screens, money needs to be put into the lab's infrastructure (Hertz-Picciotto et al., 2018). Working with overseas research labs could also help Bangladesh improve its analytical skills and bring in new diagnostic tools that are not used enough, like neuroimaging, cytokine profiling, and inflammatory biomarker analysis.

Another important area that needs to be looked at is environmental legislation. Brick kilns, garment manufacturers, and metal workshops are some of the biggest sources of particulate matter (PM2.5), VOCs, and heavy metals that might harm the development of the brain in unborn babies (Volk et al., 2013; Roberts et al., 2013).

Policymakers should make these places follow stricter rules about emissions. The country also requires a good national air-quality monitoring network, notably in Dhaka, Gazipur, Narayanganj, and Chattogram, which are all high-risk industrial areas. At the community level, encouraging the use of clean cooking fuels, better interior ventilation, less exposure to mosquito coils and biomass fuel, and fixing arsenic-contaminated groundwater would all greatly lower the amount of toxins that people are exposed to in their homes.

Improving prenatal care (ANC) programs is important for lowering modifiable ASD risk factors. ANC services must go beyond regular medical examinations and include things like dietary screening, supplement monitoring, stress evaluation, and counseling about exposure to harmful substances in the environment. Maternal care professionals must be educated in evaluating dietary intake, recognizing undernutrition, and overseeing supplement compliance, especially for important nutrients associated with fetal brain development. Additionally, focused maternal nutrition programs should stress dietary variety with nutrient-dense foods that are readily available in the area, rather than just depending on synthetic supplements (Raghavan et al., 2018).

Pregnancy mental health necessitates immediate emphasis within current maternity and child health systems. Incorporating validated psychological assessment instruments, including the Edinburgh Postnatal Depression Scale (EPDS), Perceived Stress Scale (PSS), and GAD-7 screenings into antenatal care can facilitate the identification of maternal anxiety, depression, sleep disturbances, and chronic stress—elements recognized for their influence on fetal neurodevelopment (Grote et al., 2010).

Improving mothers' emotional health and resilience can be done by expanding community-based counseling programs, encouraging peer-support networks, and getting skilled midwives and health volunteers involved in stress awareness campaigns. To improve the health of mothers in different socioeconomic circumstances, it is important to use gender-sensitive techniques. These include lowering the amount of work mothers have to do, discouraging early marriage, and encouraging mothers to make their own decisions.

It is equally essential to improve the diagnosis and early detection of ASD. Bangladesh should use standardized ASD screening instruments such as the M-CHAT, ADOS-2, and CARS-2 in hospitals, pediatric clinics, child development centers, and community health initiatives (Robins et al., 2014).

Training primary healthcare providers, such as doctors, midwives, school teachers, and community volunteers, to spot early signs of ASD would assist in finding at-risk kids before they turn three, when treatment works best. Adding ASD screening to current maternal and child health programs, school readiness tests, and vaccine schedules would make it easier for more people to get tested and cut down on the time it takes to get a diagnosis.

Setting up a nationwide ASD surveillance system and a consolidated data registry is important at the policy level so that we can keep an eye on trends in prevalence, geographic differences, risk patterns, and the results of interventions. (Matson & Kozlowski, 2011). This kind of register would help with big research projects, make it easier to plan for public health, and make it easier to provide early intervention treatments. Bangladesh should also make evidence-based guidelines that include ways to control medical, dietary, environmental, and psychosocial risks for pregnant women to stop neurodevelopmental harm that could be avoided. Lastly, encouraging collaboration between different fields is important for moving forward with research and preventative initiatives for ASD. Public health researchers, dietitians, environmental scientists, pediatricians, neurologists, psychologists, and politicians must collaborate to create context-specific research frameworks and comprehensive maternal health models. Universities, research institutions, government health agencies, and NGOs ought to establish collaborative networks to execute extensive, biomarker-driven, and culturally attuned investigations that accurately represent Bangladesh's distinctive risk landscape.

In closing, reducing the risk of ASD in Bangladesh requires a thorough and context-sensitive approach that includes optimizing maternal nutrition, reducing environmental toxins, providing mental health support during pregnancy, diagnosing early, and improving antenatal care services. Understanding how biological, environmental, psychological, and cultural factors operate together is important for making good plans for preventive and early intervention. Longitudinal cohort studies, biomarker-based assessments, and interdisciplinary collaboration will all assist in building national research capacity and creating reliable findings that can be used in many places. Enhancing diagnostic infrastructure, advocating standardized screening instruments, and broadening community-based developmental surveillance will facilitate earlier and more equitable access to intervention services. In addition, culturally relevant health education, empowering mothers, and policies that are specific to the situation are all important for making sure that improvements in maternal and child neurodevelopmental outcomes last. These initiatives together make the public health system stronger, more knowledgeable, and more open to everyone. They can help Bangladesh deal with the risk of ASD and help future generations grow up in healthier ways.

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