© INTERNATIONAL JOURNAL FOR RESEARCH PUBLICATION & SEMINAR
ISSN: 2278-6848 | Volume: 14 Issue: 02 | April - June 2023

Pediatric Neurological Disorders and Environmental Risk Factors

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DOI: https://doi.org/10.36676/jrps.v14.i2.1553

Published: 30/06/2023

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Abstract
Neurological disorders in children form developmental delay to autism spectrum disorders all have links to their environment. This case study focuses on neurotoxins in the form of air pollution, heavy metal, and chemicals as causes of neurological damage in children. It shows that low-income and rural populations are more exposed to hurricanes than high-income and urban ones, which is a subject for separate analysis. In next steps to build on this work more multifaceted prevention interventions need to be developed in terms of reducing exposure as well as improving health in targeted groups of older adults. The outcomes show the stipulation in the neurological future of the children require that there ought to be rational policies in place.

Keywords
Pediatric neurology, environmental toxins, air pollution, socioeconomic disparities, neurological disorders, preventive strategies, healthcare access.

1. Introduction

1.1 Background

Neonatal neurology remains a critical health care issue as neuro disorders impact development in cognition, movement, and behavior in children. This paper deems it necessary to establish that although it has been thought for a long time that genetic influence and other factors occurring before birth influence these disorders, research nowadays indicate that environmental risks, originating from pre- and perinatal environment, are crucial for development of the neurological disorders. Air pollution, lead, and other neurotoxins, social demographics, and geography make up a complicated world in which children are raised. It is important to establish how and what links environmental toxins with developing pediatric neurological disorders to help find ways to prevent them. In this paper, the leading environmental risks that are known to endanger child neurological development are discussed as well as the equity consideration of risk reduction solutions focused on such vulnerable population subset as children.

1.2 Research Objectives and Scope

1. To determine how the levels of risk factors in the environment can be translated into pediatric neurological disorders.
2. To examine the effects of prenatal and early life environmental contaminants such as toxins, pollutants, and chemicals on neurological states in children.
3. To determine which sociocultural and geographic factors predispose children to neurological risks before, during, and after birth.
4. To assess the effectiveness of preventions measures and programs that may help reduce impact of environmental hazards on children's neurological development.
5. To provide insights to policy makers in terms of risks that environmental lend on childhood management and neurological development.

Impacts of environmental stimuli such as pollution, toxins, and socio-economic status on the development and worsening of pediatric neurological disorders especially ADHD, ASD and Learning disability will be area of focus in this research. Other topics that the study will include as well as geographical diversity and preventive public health strategies will also be looked at.

2. Theoretical Framework

2.1 Environmental Influence on Pediatric Neurological Disorders

The concept of how environmental risk factors are linked to paediatric neurological disorders is derived from developmental neurotoxicity and ecological systems theories. Developmental neurotoxicology is concerned with the impact that risks to environment on the developing brain may impose on the brain region and functional outcome, the result of which may be autism spectrum disorders and attention deficit hyperactivity disorder (Fordyce et al., 2018). This theory points that the fragile nervous system of the children under development throughout gestation period and early childhood makes them liable to get corroded by toxins like lead, mercury, and air pollutants which are already defined by the environmentalists. Such substances are capable of interfering with such processes as neuronal development, development of synapses, functioning of neurotransmitters and result in lasting learning, behavioral, and affective disorders. A well-developed theory that seems to occupy a rather promising position for the study of the objects under discussion is ecological systems theory by Urie Bronfenbrenner. This theory argues that children develop based on the interactions in context or nested environment comprising of the family, school and other close environments up to the larger socio economic political and environment (Hertler et al., 2018). For example, ecological risks from residing in hazardous environmental conditions including pollution or having limited access to greens, directly interact with other risk factors like SES, parental health and education to worsen neurological risks among children. Regarding the latter, the principles outlined in this framework play a key role in identifying both the immediate effects of toxicants, and the effects of other environmental factors, on the development and evolution of neurological diseases in children.

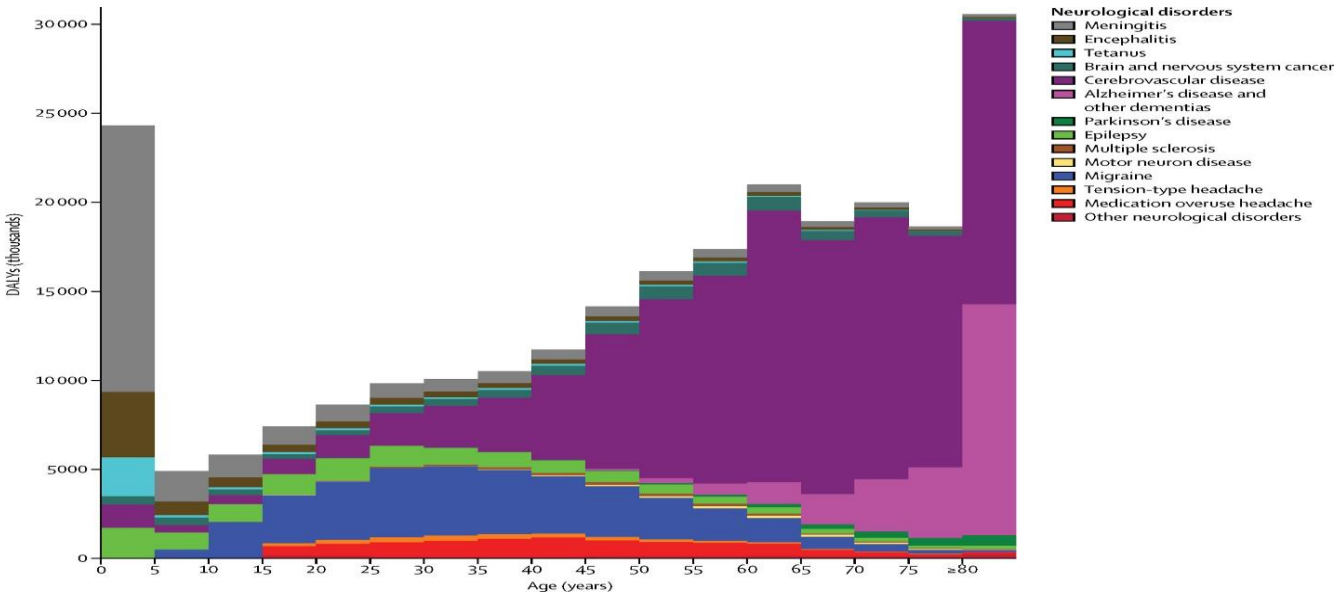

Figure 1 Global, regional, and national burden of neurological disorders during 1990–2015 (The Lancet, 2021)

2.2 Innovative Integration of the Gene-Environment Interaction Theory

Integrating gene-environment interaction theory provides additional information in understanding of pediatric neurological disorder, because it takes into consideration the interaction between inherited genes and external stimuli (Assary et al., 2018). This postulates that there are children who are born with genes that cause neurological disorders, but the effects only become noticeable later in life as a result of exposure to environmental injurious influences such as pesticides, industrial chemicals or even domestic toxins. The same patterns can be observed with genes related to ADHD; the children who possess certain markers are more probable to become ADD/ADHD affected when exposed to higher amounts of lead than children who do not possess such markers.

The G×E theory not only focuses on the development of the neural connections but also points that there are ways to intervene (Barbey et al., 2018). Screening for particular genetically based susceptibilities allows for early proactive care programs that counteract the impact of various exogenous stimuli, enhancing the model of pediatric neurology. The theory provides a concept of resilience by which specific changes in the physical environment that protect against or delay the onset of neurological disorders for genetically vulnerable children can be considered.

Table 1 Major Environmental Risk Factors and Their Associated Pediatric Neurological Disorders

Risk Factor	**Neurotoxin/Exposure**	**Associated Neurological Disorder**	**Impact on Neurological Development**
Air Pollution	Fine particulate matter (PM2.5)	ADHD, ASD	Impaired cognitive function, behavioral issues
Lead Exposure	Lead from paints, pipes	Learning disabilities, ADHD	Disrupts synapse formation, cognitive delays
Pesticide Exposure	Organophosphates, chlorpyrifos	ASD, intellectual disabilities	Neurodevelopmental toxicity, synaptic dysfunction

Prenatal Alcohol Exposure	Alcohol	Fetal Alcohol Spectrum Disorders	Disrupted brain growth, motor, and cognitive impairments
Maternal Stress	Cortisol elevation	Anxiety, ADHD	Affects brain plasticity, increases susceptibility to anxiety
Prenatal Smoking	Nicotine	Low birth weight, learning disorders	Impacts fetal brain oxygenation, cognitive function

The component integration of the proposed framework enables the consideration of external environment accessibility and biological susceptibility factors in the development of pediatric neurological disorders. It accepts a positivist view in closeness, decentralization and interdisciplinary perspective to address these problems. In addition, this theoretical context also highlights timeliness in identifying vulnerable populations, the need to offer target interventions strategies, and policies that address known environmental factors that have possible influences in the socio-economically disadvantaged communities.

3. Environmental Toxins and Their Impact on Pediatric Neurological Development

Child developmental toxicology is a researched area that shows a causal link between the extent of exposure to toxins within the environment and neurodevelopment of the child especially with reference to air pollution, heavy metals for instance lead and mercury as well as industrial chemicals. Hence, these are critical factors in designing programs that triggers environmental factors considered to cause neurodevelopmental disorders including, ADHD, ASD, and learning disabilities. The brain in early childhood is the most sensitive to the impact of outside toxins affecting neuronal function, neuro transmitter systems and brain plasticity. One key population is children who are most vulnerable because their nervous systems are still developing, they have higher breathing rates, and are likely to engage in hand-to-mouth activity in contact with pollutants. This paper will therefore establish how some of these effects can be managed or prevented in order to develop proper functioning prevention and intervention strategies for such effects so that the neurological development of children is enhance.

3.1 Air Pollution and Cognitive Deficits

Main environmental pollutants that affect neurological development in children include air pollution is one of the common one's. Cross-sectional surveys, along with longitudinal research, have also shown that raised levels of PM2.5, NO2, and O3 are accompanied by cognitive disability and behaviour disorder in children. Children such as schools-aged children that are exposed to air pollution are likely to suffer from ADHD, low IQ, and poor memory (Allen et al., 2017). PM2.5 particles are airborne particles that are small enough to penetrate the blood vessels in the human brain hence they lead to inflammation in the brain and can cause neurodevelopmental disorders. More recent evidence points to the possibility that early life pollution exposure impacts the developing brain by reducing the volume and density of gray matter and white matter and by disrupting the basic process of synaptic pruning.

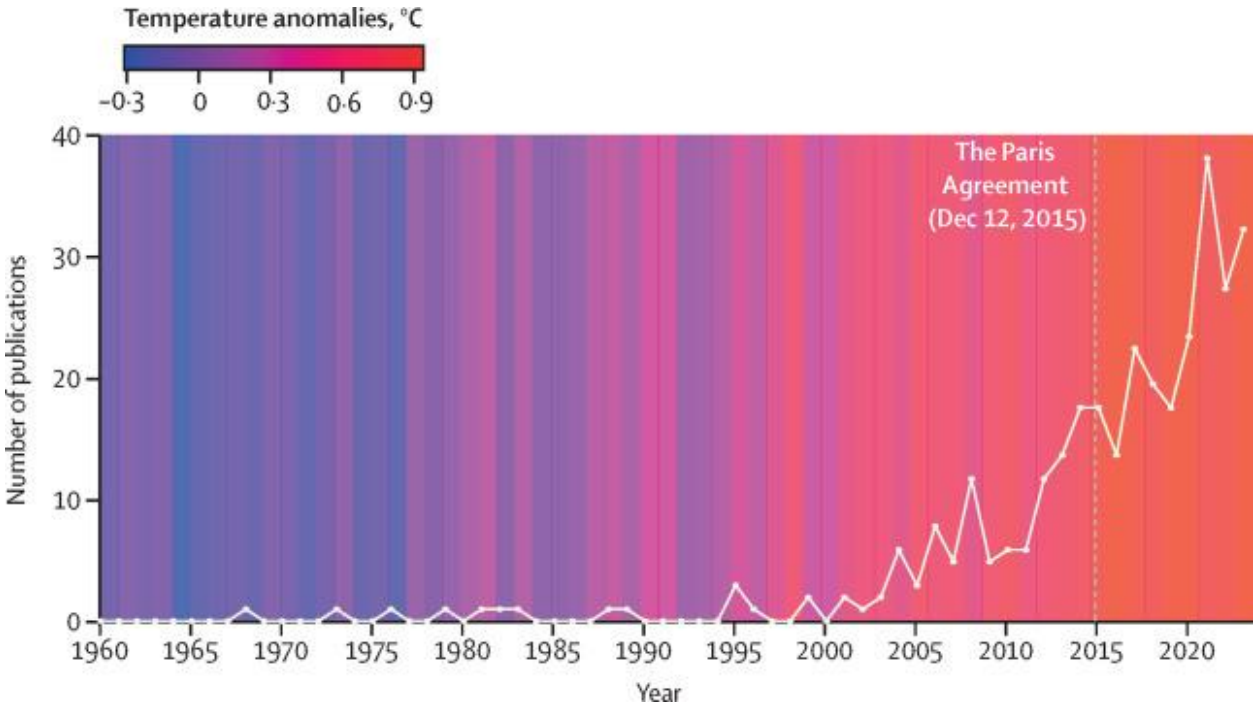

Figure 2 Climate change and disorders of the nervous system (The Lancet, 2021)

Table 2 Association Between Air Pollution Levels and Cognitive Outcomes in Children

Study Population	**Air Pollution Exposure (PM2.5 levels in µg/m³)**	**Cognitive Outcome Measured**	**Average IQ Score Reduction**	**ADHD Symptom Severity (Scale 1-10)**
Children (ages 6-12, urban)	High (15-20 µg/m³)	IQ Scores	-3.5 points	7.2
Children (ages 4-7, suburban)	Moderate (10-14 µg/m³)	Working Memory	-2 points	5.4
Infants (0-2 years, rural)	Low (5-9 µg/m³)	Attention Span	No significant reduction	3.1

A negative relationship between exposure to air pollution levels and scores indicating cognitive ability is also revealed here in table 2. The study also screened the general acceptance of the respective hypotheses among the student population and proved that the general acceptance is higher among urban children who are more exposed to pollutants as a result of traffic and industrial activities since they demonstrated a more dramatic decline in IQ scores than their counterparts from suburban or rural backgrounds. This works to support the hypothesis that air pollution plays a role in the neurological development of any population and may, in fact, contribute to worsening neurodevelopmental diseases in those exposed to it.

3.2 Heavy Metals: Lead and Mercury

Lead and mercury toxicity still pose a great threat to developmental cognitive outcomes of children especially those in low-income countries where there is outdated Metallic and Industrial emitters without regulation. Lead in the form of lead paint, water service pipes and leads, and some dust is known to cause dangerous impacts on children's brain (Karri et al., 2016). In this case social, health, education and

economic implications are occasioned by the toxic heavy metal with effects such as irreversible cognitive deficits at very low levels of leads, decreased academic achievement besides other behavioral problems. The same is true for another heavy metal, namely mercury which can be inhaled from industrial emissions or ingested from fish and seafood and which is dangerous during prenatal development.

Lead has toxic effects on the calcium ion receptor sites of neurons and inhibits neuron transmission from one neuron to another thereby leading to deficits in executive ability, memory, and attention. It is seen that there is 1.5 points decrease in academic achievements for every ten units of microgram/day increase in blood lead level and that there is very real possibility of restricted intelligence quotient, hyperactivity and learning studies among children. however, mercury impairs the development of the nervous system in general and in particular the coordination of movements, attention and the ability to process sensory input. Especially, prenatal mercury exposure had adverse effects on child's learning ability and development, including language delays, and lower verbal intelligence quotient.

Table 3 Blood Lead Levels and Associated Neurological Outcomes in Children

Blood Lead Level (µg/dL)	Neurological Outcome	Cognitive Decline (IQ Points Lost)	ADHD Prevalence (%)
< 5 µg/dL	No significant neurological impact	0 IQ points	2%
5-10 µg/dL	Mild cognitive impairment	-3 IQ points	12%
10-20 µg/dL	Moderate cognitive impairment	-7 IQ points	25%
> 20 µg/dL	Severe cognitive and behavioral deficits	-12 IQ points	40%

As demonstrated in Table 3, the effects of blood lead on children's cognitive function are available from numerous studies showing the dose-response relationship between BLLs and reduced cognitive performance. Specifically, children with BLL of 10 µg/dL or greater have sufficient evidence that exhibits the negative impacts lead has on the children's learning ability as well as their probability of developing ADHD by the time they are six years of age. This shows the urgent need to minimise lead source and prevent their impact in homes or virtually any geographical location affecting neurological development.

3.3 Pesticides and Neurodevelopmental Disorders

Another environmental toxin includes pesticides, of which organophosphates have been found to cause neurodevelopmental effect on children. Organophosphates cause neurotoxicity because they affect the enzyme referred to as acetylcholinesterase crucial in managing of neurotransmitter. Research has established a link between early exposure to pesticide through prenatal and early childhood and developmental issues such as, developmental delays, low IQ and increased risk for ASD (Mostafalou et al., 2018). Farm based children are vulnerable to the effects of pesticide residues through air, water and food borne, to the extent of having more affected neurological system. Pregnant women exposed to pesticide have been found in other research papers and articles to have fetuses with abnormal brain structures and respective cognitive and behaviours.

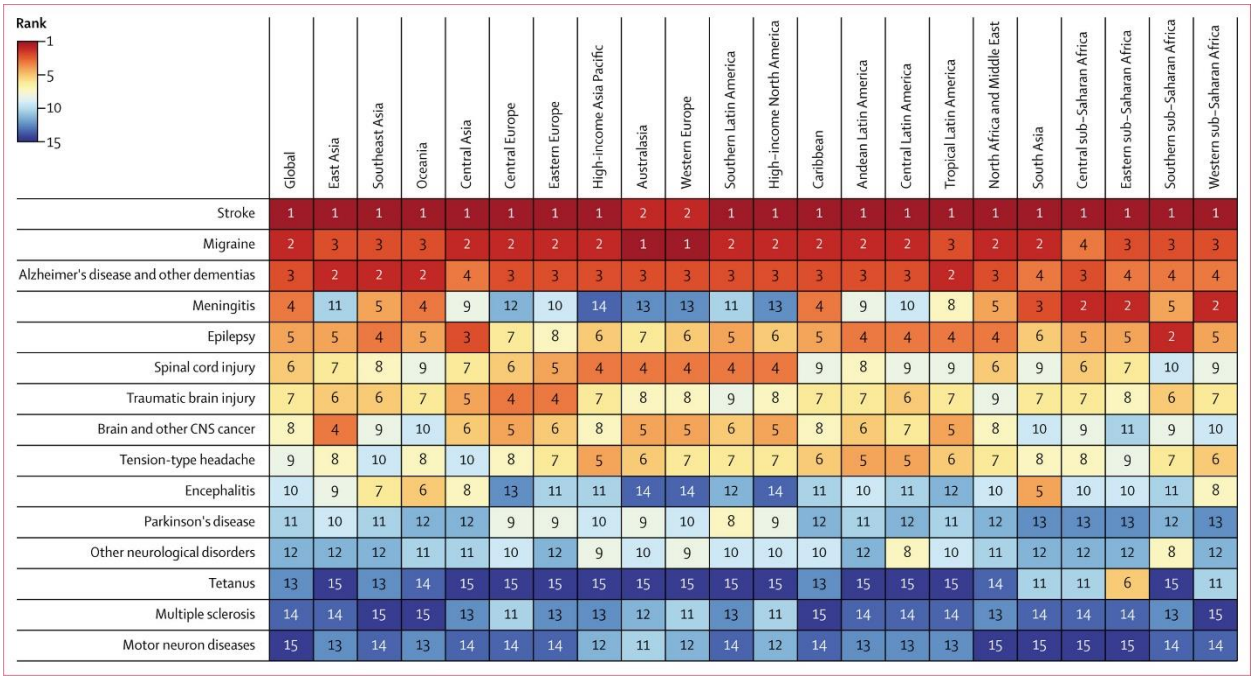

Figure 3 Global, regional, and national burden of neurological disorders, 1990–2016 (The Lancet, 2021)

Newer studies are also beginning to explore the interactive effects of joint and combined toxicity of various environmental xenobiotics where children who are exposed to multiple air pollutants, heavy metals and pesticides will have increased neurodevelopmental disabilities (Claus et al., 2016). This conceptual model of multiple toxins underlines the necessity for the environmental health approaches that address the reduction of children's vulnerability to a whole range of neurotoxins.

Globally, it is established that exposure to end toxins is a major impediment to the neurological development of children and if left unchecked, it will result to long term performance of the brain in terms of intellectual ability, social behavior and academic achievement. Additionally, since these toxins are now nearly ubiquitous in the external environment, efforts to limit human exposure through better regulatory standards, water and sanitation, and increased prevention measures are paramount for child neurological protection.

4. Socioeconomic and Geographical Disparities in Exposure to Neurological Risk Factors

Socioeconomic and geographic characteristics of families are highly relevant to the question of children's exposure to neurological risk factors. These differences tend to determine the extent of contact with the environment, health care provision and general wellbeing which affects neurological functioning. Lower SES and geographical isolation increase children's susceptibility to toxic, polluted environments and poor diet, all of which are associated with neurodevelopmental diseases. It is equally important to understand the relationship between socioeconomic status and geographical locations and the level of exposure to these risk factors so as to center on reducing neurological diseases burden in such regions.

4.1 Socioeconomic Disparities and Access to Safe Environments

The study reveals that there is a close positive relationship between SES and the level of environmental risk at the community level. The young from poor families are also likely to live in polluted areas and in sub-standard houses, and the sample respondents' child accessibility to child friendly green spaces is negligible (McHutchison et al., 2017). These children are more susceptible to environmental hazards such as lead in

dilapidated buildings, auto exhaust fumes, and industrial products that are related to bad brain formation or neurodevelopmental disorders inclusive of; ADHD and ASD. Some of these independent studies include the fact that low SES brackets children have high risk of acquiring neurological diseases due to costly exposure to toxins, inadequate nutrition and poor antenatal care.

When the living condition of off springs is considered the linkage between poverty and neurological outcome becomes more enhanced. Extended families of low-income sources live in close proximity to highways, industrial facilities or buildings which are already dilapidated with poor infrastructures to support children thereby exposing them to toxic substances. Financial difficulties also take a lot on the nerves, and this may be the reason why neurological conditions are more worsened. Cortisol affects the body and brain resulting into undesirable changes in the areas that are associated with memory, learning and emotional control areas of the brain. This results in a cycle such that poverty results to high likelihood of being exposed to neurotoxic environments thus lowering down the capabilities of children.

Table 4 Socioeconomic Status and Neurological Risk Exposure

Socioeconomic Level	Common Environmental Exposure	Prevalence of Neurodevelopmental Disorders	Average IQ Impact
Low	Lead, Air Pollution, Poor Housing	ADHD, ASD, Learning Disabilities	-7 IQ points
Middle	Moderate Pollution, Occasional Exposure	ADHD, Behavioral Problems	-3 IQ points
High	Minimal Pollution, Cleaner Environment	Lower prevalence of neurological disorders	No significant impact

Table 4 above shows that children from the low socio-economic background of the society they experience more risks of neuro development risks factors that are evidenced from their raw scores of cognitions. In order to combat these disparities, policies signed on environmental quality and equity will seek to respond to the social issue, by offering poor families clean air, homes and education the fight the impact of the contaminant that they are subjected to.

4.2 Geographical Disparities: Urban vs. Rural Exposure

Another significant independent variable describing neurological risk exposure is geography: there are vast differences in environmental contaminants and medical facilities between urban and rural settings. This is because pollution in urban areas through car productions, industries among others and burning of waste products affects air purities hence leading to children neurological deterioration. Those attending school in a crowded district; or closer to industrial areas; experience a more dramatic decline in IQ and the probability of behavioral disorders. For instance, rural children are not as likely as urban children to breathe in polluted air but they may be exposed to pesticides during farming activities and a majority of them do not have access to health facilities through which diagnosis and treatment of neurodevelopmental disorders can be undertaken.

Also, sanitation, clean water, paved roads and many may not be easily accessible in the rural areas which increases the child's vulnerability to being exposed to environmental hazardous that impact on the neurological development (Allen et al., 2017). For instance, water borne diseases such as arsenic have remained a common problem in many rural areas affecting the children's neuro development when they

continually ingest this toxin. There's also the issue of stigma; children from rural regions may lack access to early intervention for ADHD or ASD and thus those symptoms will worsen with time.

Table 5 Urban vs. Rural Neurological Risk Factors

Geographical Region	**Primary Environmental Risk Factor**	**Prevalence of Neurological Disorders**	**Access to Healthcare**
Urban	Air Pollution, Lead Exposure	Higher ADHD, Cognitive Decline	Better, but varied by SES
Rural	Pesticides, Arsenic in Water	Developmental Delays, ASD	Limited and delayed
Suburban	Moderate Pollution, Pesticides	Moderate Neurological Impacts	Access better than rural

Table 5 shows the differences in risk factors between the urban and rural areas of study. Although urban children have better access to healthcare, they have greater neurological pollution risks than rural children who lack adequate healthcare and who are exposed to pesticides. Both situations demonstrate the important role of targeting different area through the need to minimize children's vulnerability to environmental hazard and enhance the probability of a more positive health status.

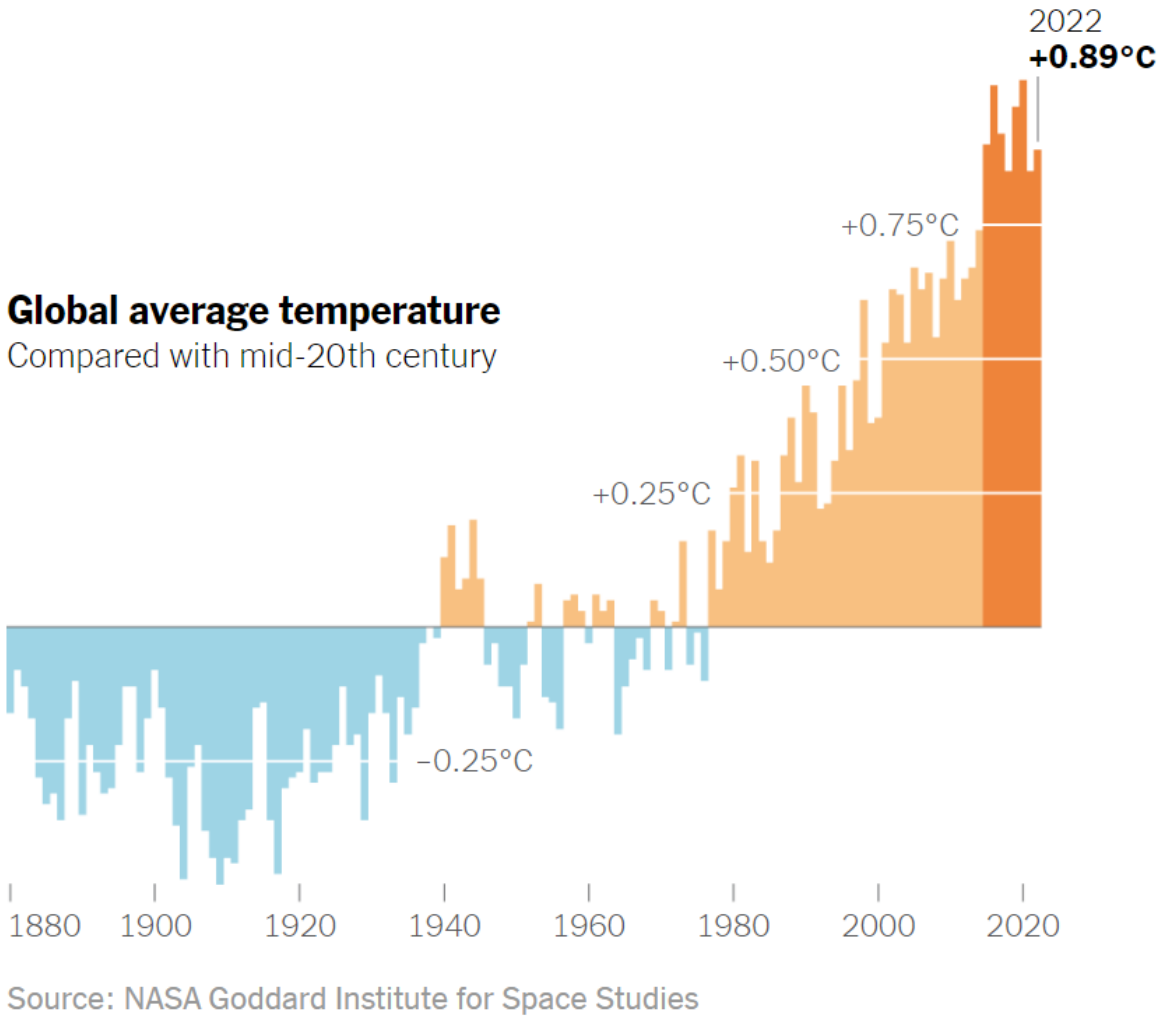

Figure 4 Global Temperature (The New York Times, 2021)

4.3 Intersection of Socioeconomic and Geographical Factors

This implies that the level of development in communities affected and geographical location improves vulnerability to neurological disorders among children. Poverty and environmental degradation contributions that affect the client are: Urban poor families are said to be bearing the 'double jeopardy of poverty and environmental." These children have a very weak education and health sector with or with little or no-Version of standard education and health care services to counter these effects of such exposures. For example, a child growing up in low-income urban family may have to play near the polluted roadside, their families cannot afford healthy food or medical attention that could reduce the impact of such exposure.

Low-income rural families may experience geographic location stall which limits the child's opportunity to consult pediatric neurologists who can help identify and manage the condition at an early stage. This lack of access increases the chance for never being screened or receiving treatment, which results in worse overall outcomes (Harding et al., 2019). It means that health promotion and social policies for children should targets children in urban and rural low-income settings.

Implementation of these ideas entails a combined effort of socioeconomic and geographical concepts to eliminate these problems. Measures such as raising density of infrastructures in urban areas to reduce emission of pollutants, ensuring rural populace have access to clean water, enhancing funding for pediatric neurological disorders among children in under privileged areas among others, are important. Furthermore, the knowledge that informed parents and care giver receives on the impacts of environmental hazards provides the communities requisite information to request protection and alteration of policies and laws.

5. Preventive Strategies and Policy Recommendations for Reducing Environmental Risks

1. Regulation and Control of Environmental Pollutants

- Strengthen governmental measures particularly, nitrogen dioxide, particulate matter (PM2.5) and lead that is commonly associated with negative impacts on children's' developing brains.
- Strengthen laws governing emissions of toxic products into the atmosphere and water front's especially in the informal settlements in urban areas of the province and the country.
- Strengthening of the already existing environmental policies together with more investigations concerning industries and urban developers.

2. Cleaner Air and Water Initiatives

- Advocate for polices that will discourage the use of gasoline automobiles by encouraging the use of electric or hybrid cars, subsidization of public means, and erection of car-free special areas for densely populated areas.
- Strengthen the drinking water treatment processes in the rural and urban areas to eliminate exposure to dangerous substances such as lead, mercury, pesticides and so on that are a common sight in low-income regions.
- Available, affordable and adequate quality water in the rural and developed communities should be increased with venture on more infrastructures to fix to get more water sources fitted for use by humans being and providing well equipped means to maintain the water systems.

3. Urban Planning and Infrastructure Development

- Incorporate green infrastructure in Urban designs by aiming at increasing number of parks, trees and conditions under which children are not exposed to risky environment and encouraged to play in child-friendly environments (Arango et al., 2018).
- Upgrade the living conditions of poor households by ensuring noncompliance with building laws that require the eradication of lead in-housing paints; banishment of mould and asbestos-rich indoor air.
- Construct residential estates in areas which are not close to Industries and heavily transported stretches of the highways so as to minimize children's exposure to neurotoxic agents which are more common in these regions.

4. Health Equity and Access to Care

- Formulation of policies that would encourage delivery of health care services especially for children who come from the low income or rural areas as this area are in most cases, faced with-(deficient-) inadequate health care provisions. Mobile clinics or telehealth should be offered in order to make neurological diagnoses and treatments promptly.
- Provide more funding to continue early childhood health screenings such as neurodevelopmental evaluation and incorporate toxicology history management into at risk population.

- Promoting inter-disciplinary cooperation between environmental sciences, health care system and departments of public health with the goal of developing uniform health care approaches targeting the neurological development issues correlated with both the environment and clinic.

5. Educational Programs and Community Awareness

- Set up public awareness programs held at the community, school, and parents' level focusing on environmental hazards specifically the effect of toxins on children's brain. Suggestions must involve the information concerning with air borne and water borne contaminants, the necessity of prenatal check-up, and how to avoid contact with neurotoxic substances within home environment.
- Create courses on risks of the environment that contribute to pediatric neurodevelopmental disorders targeting health care workers, teachers and policy makers.
- Form relationship with supervised NGOs because in order the targeted population which are the low-income families be equipped with the knowledge and tools as to be able to shield themselves and or their environment from adverse environmental effects like using lead safe practices and or having a clean environment within their neighborhoods.

6. Future Direction

It is imperative that paediatric neurological disorders and environmental risk factors research should employ more sound approaches which blend environmental science approaches, public health and neurology. More prospective investigations must be performed to determine the effects of toxins including lead, pesticides, and industrial pollutants on children's neurodevelopment. Furthermore, policy driven research should review, its method for assessing the efficacy of preventive interventions in minimizing environmental burden especially in low income and rural settings. These are cloth-based sensors for real time exposure and the cardinality of one's exposure to pollution to help in decisions on preventions. There is a need to adopt multisectoral cooperation mechanisms that connect government agencies, intensified healthcare facilities, environmental groups, policymakers, researchers, and the community to develop and set up better systems for the defense of children's neurological well-being. Moreover, international efforts should be directed to a particular aim, and it is to coordinate the regulation so that all children may have improved safety of environment where they live.

7. Conclusion

Child neurological disorders have been associated with environmental conditions like air pollution, toxic chemicals, and lead to toxicity all of which present important threats of child neurological development. This research demonstrates a lack of socioeconomic and geographic equality in terms of suffering from environmental toxicities that affect low-income groups of people. So, to avert the case of developing such risks need appropriate policies and measures including strengthened policies on health care services, public health initiatives, and improved measures of enhanced health care services. It is obvious that future research and policy concerns related to these risks have to investigate this issue from environmental, medical, and socioeconomic perspectives. Such approaches will require the support of all stakeholders including public health quacks, environment al regulators, healthcare practitioners and stakeholders in the community. If public health stakeholders and governments elevate the neurological health of children in environmental policies, society can prevent these environmental risks from becoming worse for future generations of especially vulnerable children.

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