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Environmental Pollution as a Causative Factor of Birth Defects in the Niger Delta Area of Nigeria.

Abbey M,[1] Kua P.[1]
[1]*Department of Obstetrics and Gynaecology, Rivers State University Teaching Hospital, Port Harcourt, Rivers State, Nigeria.*
Corresponding Author: Dr. M Abbey

Abstract:
Background: *The Niger Delta, specifically, Ogoniland in Nigeria was declared by the United Nations in 2011 as a zone of environmental disaster. The prevalence of birth defects in the region was high at 20.7 per 1000 life-births but unfortunately, not much was known about the impact of environmental pollution on the prevalence of birth defects in the core Niger Delta (Rivers and Bayelsa States).*
Objective: The objective of the study was therefore to ascertain the contribution of environmental pollutants to the aetiology of congenital abnormalities in the Niger Delta.
Methodology: *The study was of mixed methods – systemic review and descriptive observational. 49 published works on environmental pollution were reviewed and where environmental factor was blamed for birth defects, the prevailing situation was extrapolated to the environmental situation in the Niger Delta, Nigeria. Regional register of birth defects and guidelines on its management were looked for. A qualitative assessment of environmental pollution in the region was carried out.*
Results: *There was no regional register of birth defects or guideline on their management and also no record of causative factors of birth defects in the Niger Delta. The causes of birth defects in the Delta were largely unknown. The known factors were of genetic and non-genetic origin including environmental pollution. The environmental factors were neglect of environmental protection policies and laws in the region, drinking of contaminated water with heavy metals and chlorinated and aromatic solvents, occupational exposure to environmental teratogens, toxic waste disposal including landfill sites and incineration of waste and exposure to naturally occurring radioactive substances.*
Conclusion: *The known causes of environmental pollution in the Niger Delta interact with genetic, nutritional and socioeconomic factors and sometimes act in isolation to cause birth defects.*
Key words: *Environmental pollution, birth defects, Niger Delta, Nigeria*

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I. Introduction

Congenital anomalies also known as birth defects or congenital malformations was defined as structural or functional anomalies that occur during intrauterine life and can be identified prenatally, at birth, or sometimes may only be detected later in infancy, such as hearing defects. [1] Serious abnormalities are life threatening or have the potential to result in disability (physical, intellectual, visual or hearing impairment, or epilepsy). Every year worldwide, an estimated 7.9 million children were born with serious birth defect of genetic or partly genetic origin. [2] Over 1 million more infants were born with serious birth defects of post-conception origin. [3] Thus, an estimated 9 million infants – representing approximately 7 percent of all births – were born annually with serious birth defects that may kill them or result in lifelong disability. 94% of the defects (i.e. 8.46 million infants) occur in developing countries of the world to which Nigeria belongs. So, it was obvious that the burden of congenital abnormalities in Nigeria and other developing countries was enormous and therefore demanded adequate attention from Government and healthcare providers of those countries.

The inhabitants of the Niger Delta are fishermen and farmers. Unfortunately, marine life in the area is almost in extinction and the yield from farming activities is not even enough for personal consumption. The main explanation for this woe in the oil-rich Delta is that the region has been plagued with significant accidental, deliberate and iatrogenic catastrophic environmental degradation over the past 52 years by the products of crude oil exploration, extraction, refining, transport, and usage and also from many other sources. The Niger Delta is the industrial powerhouse of Nigeria because of its abundant oil and gas resources, seaports, fertilizer plants, and many other firms. In the region, there have been issues of oil pipe vandalism and oil spillage, inappropriate discharge of waste waters, gas flaring, acid rain, toxic leakage from underground petroleum storage tanks, dumping of dangerous chemical wastes, use of cars that are not road worthy, burning

of biofuel including kerosene, bush, biomass, coal, and inappropriate incineration of refuse. [4, 5] The sources of pollution have led to the contamination of soil, water, and air with heavy metals (arsenic, mercury, cobalt, manganese, etc), different gases (sulphur dioxide, nitrogen dioxide, ozone, and carbon monoxide), particulate matters, benzene, toluene, ethyl benzene, xylem, other volatile organic compounds, [6 -8] and other teratogens.

Mothers are exposed to the environmental pollutants during the critical period of ontogenesis (4–10 weeks) and throughout pregnancy. The abundant environmental teratogens can cause congenital abnormalities through preconception mutagenic action (maternal or paternal) giving rise to chromosomal abnormalities and single gene disorders - autosomal dominant, autosomal recessive, X-linked disorders and multifactorial malformations which are partly genetic or through postconception teratogenic action in pregnancy, depending on the nature of the teratogen and the precise timing of exposure – embryonic or fetal period. [9] Therefore, it is not surprising that women who have lived in that environment for years should experience high prevalence of congenital abnormalities of unique pattern, than women who live in other region of Nigeria. The prevalence of birth defects in South Southern Nigeria represented by the University of Port Harcourt Teaching Hospital was 20.73 cases per 1,000 live births. [10] The predominant abnormalities in that same study were those of the central nervous system at 27.0%, gastrointestinal system 11.95%, cardiovascular system 10.69%, anterior abdominal wall 8.18%, skeleton 6.29%, and chromosomal abnormalities at 5.6%. In the North Eastern Nigeria, the prevalence was 5.51% while the predominant abnormalities were those of the gastrointestinal system at 34.5%, unclassified abnormalities at 33%, and those of the central nervous system at 13.6% of the total birth defects. [11] In the South Western Nigeria, the prevalence was 15.84 per 1000 live births while the predominant abnormalities were those of the cardiovascular and gastrointestinal systems, followed by the abnormalities of the musculoskeletal, cardiopulmonary, and genitourinary systems. [12] In the South East, abnormalities of the gastrointestinal system predominated at 36.7% followed by those of the skeletal and then the cardiovascular systems and the prevalence was 4.15 out of 1000 live births. [13]

Therefore, we hypothesize that the inhabitants of the core Niger Delta States (Bayelsa and Rivers states) should have abundant and more environmental teratogens capable of causing birth defects than any other region in Nigeria and probably the developed world. The present work was therefore executed at the UPTH in the Rivers State with a view of testing our hypothesis.

Aim: The purpose of this study was therefore to ascertain the contribution of environmental pollutants to the aetiological factors of congenital abnormalities in the Niger Delta area of Nigeria.

II. Material and Methods

Setting: The study was carried out at the University of Port Harcourt Teaching Hospital in Rivers State which is situated in the South-South region of Nigeria called the core Niger Delta.

Study Design: This was a mixed method study – descriptive observational and systemic review.

Actual methods: We reviewed published studies on causes of fetal abnormalities in different regions of Nigeria and also in different parts of the world with specific attention to environmental pollutants and also regions and countries all over the world that have similar socio-economic and environmental terrains like the Niger Delta. We carried out literature search using Pub med (MEDLINE), Biomed central, Google and Cochrane database. Keyword search statements used were 'Environmental pollutants in the Niger Delta', 'Air pollution and birth defects', 'Water pollution and birth defects', 'Etiology of birth defects in the Nigeria' and also in different regions of the country, 'Causes of congenital abnormalities in Nigeria', Congenital abnormalities in developing countries, 'Soil pollution and birth defects', 'Environmental pollution and congenital abnormalities', Petroleum exploration, extraction, refining and birth defects;, 'Burning of biomass and fossil fuel and birth defects; Produced waters and birth defects', landfills and waste dumps and births', etc. The inclusion criteria for the literature search were as follows: the literature must be published after1990 with a view of knowing more about recent developments, the studies must be associated with similar terrains like the Niger Delta, the study must be on environmental pollutants and lastly pathogenesis of birth defects caused by environmental pollutants. The literatures were synthesized by two researchers and relevant information was retrieved from them and agreement on inclusive data was reached by dialogue. Where environmental pollution was blamed for birth defects, the prevailing situation was extrapolated to the present condition in the Niger Delta. Furthermore, we looked for Nigerian National, regional and State registers on birth defects and guidelines and strategies on the management of the abnormalities. We also conducted a qualitative review of the socioeconomic aspects of life and sources of environmental pollution in the core Delta region of the country with a view of having an insight into possible causative factors of birth defects in the regions. This was carried out by reviewing Nigerian statistics on the socioeconomic development of the regions and interactive and telephone communication with the locals and consultants Obstetricians and Pediatricians in the two major University Teaching Hospitals located in each of the States.

III. Result and Discussion

Number of articles identified through search = 120. Number of articles dropped for duplication = 30. Number of articles screened = 90. Number of articles that did not meet the inclusion criteria and therefore dropped = 41. Number of articles that met the inclusion criteria = 49.

III1. Nigerian national and regional Birth defects register: There was no Nigerian national or regional register of birth defects. There was also no record of causative factors of birth defects, neither was there any literature or publication that specifically dealt with the impact of environmental pollution in the Niger Delta on the prevalence of birth defects in the region.

III2. Nigerian national and regional guideline on the management of birth defects: There was no national or regional guideline on the management of congenital abnormalities in Nigeria. There were however pockets of tertiary centre-based studies in all the geopolitical regions of the country on the prevalence and patterns of regional birth defects.

III3. Environmental pollution and birth defects in the Niger Delta: Maternal exposure to certain pesticides may increase the risk of having a fetus or neonate affected by congenital anomalies. Physical agents such as radiation and environmental pollutants can also cause birth defects. In Nigeria there are laws on the control of radiations and environmental protection from different sources, but they are not implemented. Therefore, congenital abnormalities from radiations and environmental pollutants are rife in the country. This is particularly so in the Niger Delta which has been exposed for the past 55 years to environment devastation by the products of petroleum exploration, extraction, refining, transport and gas flaring among other unfriendly environmental factors. There is unfortunately no statistics on possible environmental causes of fetal anomalies in the Delta.
Environmental pollution can cause congenital anomalies through preconception mutagenic action or postconceptional teratogenic action. [9] Preconception mutagenic effects may include chromosomal anomalies and syndromes as a result of new mutations. Postconceptional action depends on the precise timing of exposure to the teratogens. Organogenesis starts from conception till about the 10^{th} week of pregnancy; it is during this 'sensitive period' that exposure to a teratogenic agent may lead to an anomaly. Thus, a particular pollutant or chemical may cause a congenital anomaly after exposure in, say, the sixth week of development, but exposure during the previous or succeeding week may have no effect. Where a child has more than one anomaly, this may be because exposure has covered a number of sensitive periods for different congenital anomalies, or because exposure at one developmental stage has a number of different effects on organogenesis.
Much attention was paid to environmental pollution as a causative factor of birth defects because of the presence of several sources of pollution in the Niger Delta, ranging from usage of old cars with poor exhaust function and generators for light to the unregulated processes of oil and gas production and chemical industries in the region. Ogoniland which is one of the main clans in Rivers State, a State in the Niger Delta was in 2011 declared a zone of environmental disaster by the United Nations. [14] So environmental pollution in the present study was considered under different subheadings as outlined below.

III3a. Air pollution and congenital abnormalities in the Niger Delta.

An association has been established between cardiac defects, including ventricular septal defects and carbon monoxide exposure. [15] Another study showed an increased risk of congenital heart diseases (CHDs), ventricular septal defect (VSD), and tetralogy of Fallot (TF) with increasing Ozone exposure and also a positive association between carbon monoxide (CO) exposures during the third month of pregnancy and VSD. [16] A meta-analyses of 10 studies showed that nitrogen dioxide (NO2) and Sulphur dioxide (SO2) exposures were related to increases in the risk of coarctation of the aorta and tetralogy of Fallot while particulate matter ≤ 10 μm exposure was related to an increased risk of atrial septal defects. [17] In another study, NO_2 concentrations were significantly associated with coarctation of the aorta (OR = 1.20 per 10 ppb, 95% CI, (1.02, 1.41). [1]

Unfortunately, in Nigeria including the Niger Delta region ambient air quality assessment is not done except some isolated environmental impact assessment by companies in their immediate area of operation. Worse still, there is no national or regional statistics on the prevailing concentrations of named air pollutants and their ill effects including birth defects and consequently no national strategy on dealing with the problem. [19] There are therefore many questions that deserve urgent answers. Does air in Nigeria, especially the Niger Delta region satisfy the WHO or the Nigerian standard for good quality air? Is the air detrimental to human health? Is it safe to continue to live there? We have no answers to these questions. Countries such as South Africa, Jamaica, Cuba and many others that fall within the bracket of developing countries as Nigeria conduct air quality check daily. Why is it not done in Nigeria or specifically in the Niger Delta, given its famous ascription by the United Nations UNEP in 2011 as a region of environmental disaster.[14, 20] In contrast to what is

obtainable in Nigeria and in many developing countries, ambient air quality is checked many times a day in developed countries.

III3b. Drinking water contamination and congenital abnormalities

Inorganic contaminants in drinking water that have been studied in relation to congenital malformation risk include heavy metals (lead, cadmium, arsenic, barium, chromium, mercury, selenium and silver), nitrates, nitrites, fluoride and other elements. Two studies reported conflicting results in relation to neural tube defects and lead in water supply. [21] An Italian study reported a positive association between lead pollution emitted by ceramic factories and the prevalence of cardiovascular anomalies, oral clefts and musculoskeletal anomalies. [22] When oil is pumped out of the ground, a mixture of oil, gas and water emerges. The wastewater (known as "produced water" or "formation water") carries such heavy metals, namely Arsenic, Cadmium, Cyanide, Lead and Mercury, maintenance wastes (including industrial solvents and acids), volatile aromatic hydrocarbon and the related effluvia of the oil-extraction process. [23] This is exactly the situation in the Niger Delta area of Nigeria where there is constant pollution of water bodies. These substances can adversely affect humans and they have the potential to cause embryopathy. Generally, the produced water can be treated using a range of mitigation techniques including filtration, biological processes, and reverse osmosis before being reintroduced into the environment. But these methods entail a great deal of expenses and seem to be employed selectively. Following treatment and in some cases without any treatment much of this wastewater is discharged into Rivers and the Sea, e.g. Warri River in the Niger Delta. [24] Sometimes, the waste water is disposed into oil-waste pits.

Mercury contamination of fish has become an increasing route of human exposure to this neurotoxin, believed to cause birth defects, heart problems, severe neurological disorders ("Minamata disease") and death with very high levels. Mercury is found in fish - groupers, amberjack, yellow fin tuna, reds snapper, swordfish and others. These fish may have mercury levels that makes them unsafe for human consumption because of possible ill effects on mother and baby and others. It is known that damage to the fetal brain and microcephaly can result from high exposures to mercury. [25] Some studies have been supportive of a potential effect of high nitrate levels on central nervous system defects, [26] cardiac defects [27] and anencephaly. [28] This should also be applicable to the Niger Delta area of Nigeria where there should be high levels of nitrates in ground water because of oil production activities, especially gas flaring, acid rain, indiscriminate disposal of waste and poor sanitation? A study in North Cornwall, United Kingdom examined outcomes of pregnancy after an incident where Aluminium Sulphate was added to the local water supply accidentally. [29] There was an increased rate of talipes among the exposed pregnancies. Acid rain produced in the Niger Delta area of Nigeria leaches lead, copper and Aluminium into drinking water, therefore, there is high chance that ground water and bore hole water that people drink in the Niger Delta area of Nigeria may have high concentrations of Aluminium and consequently give rise to a high incidence of talipes.

III3c. Exposure to Naturally occurring radioactive materials (NORM).

Norm are commonly found in underground geologic deposits and are frequently brought to the surface during crude oil recovery and also leached to the environment (water) as a result of acid rain e.g. radium. Crude oil recovery and acid rain occur in the Niger Delta area of Nigeria and is very likely that the inhabitants there will be exposed to NORM. Unfortunately, new studies reveal that even low-level NORM radiation may have mutagenic impacts. [30]

III3d. Chlorinated and aromatic solvents (trichloroethylene, benzene) in drinking water and occupational exposure to environmental teratogens.

They enter drinking water from leaking underground storage tanks, landfill, and other waste disposal facilities. A typical example was in Woburn, Massachusetts where toxic chemicals (industrial solvents, mainly trichloroethylene) from a waste disposal site were detected in municipal drinking water wells. Residents of Woburn reported a cluster of childhood leukemia and pregnancy outcome survey found associations with congenital abnormalities of the eye, ear, central nervous system, oral cleft and chromosomal anomalies (mostly Down Syndrome). [31] The same situation should be expected to be worse in the Niger Delta area of Nigeria where chlorinated and aromatic solvents should be abundant in drinking water due to accidental or deliberate oil spillage, inappropriate discharge of waste waters, building of underground petroleum reservoir near sources of drinking water, innumerable landfills and waste pits which are built by multinational oil companies. This problem is made worse by non-enforcement of laws guiding disposal of industrial waste in Nigeria.

Chlorination by-products which are halogenated solvents, predominantly trihalomethanes THM (chloroform, bromodichloromethane, dibromochloromethane and bromoform) have been associated with specific anomalies, including NTD, oral clefts, cardiac anomalies and urinary tract defects but it is not yet clear which of them represent causal associations. [26, 31, 32] Occupation (e.g. nursing, processing food and beverages,

farming, textile dye and leather industries, spraying pesticides) and also possible exposure to noxious agents such as organic solvents, anaesthetic agents, sterilant, viruses, pesticides, paints, X-radiation, have been reported to be associated with a high risk for NTD. [33, 34]

III3e. Waste disposal (landfill sites and incinerators) and contaminated land

The contribution of waste disposal to birth defects was illustrated with some specific examples. Large quantities of toxic materials (residues from pesticide production) were dumped at a landfill in Love Canal in New York during the 1930s and 40s, followed by the building of houses and a school on and around the landfill in the 1950s. By 1977 the site was leaking and chemicals were detected in neighbourhood creeks, sewers, soil, and indoor air of houses. [35] Chemicals detected at Love Canal were primarily organic solvents, chlorinated hydrocarbons and acids, including benzene, vinyl chloride, PCBs, dioxin, toluene, trichloroethylene and tetrachloroethylene. There was increase in the occurrence of different birth defects in the area surrounding the Love canal. [36]

Geschwind et al found a 12% increase in congenital malformations (nervous system, musculoskeletal system, and skin, hair and nails) for people living within 1 mile of 590 hazardous waste sites in New York State. [37] Some associations between specific malformation types and types of waste were evaluated and found to be significant. A European multisite study reported a 33% increase in risk of all non-chromosomal birth defects (Neural tube defects, specific heart defect) for residents living within 3 km of 21 hazardous waste landfill sites in 10 European regions. [38] Therefore if toxic waste can cause embryotoxicity, it means Nigeria should have more associated abnormalities than in the developed countries as already reviewed. This is because in Nigeria, waste generated from within the country and from abroad are dumped in different places unchecked. In all cases of dumps, locals do not know the content and the implication of the waste to them and their environment.

Maternal ambient exposures to airborne chemicals in close proximity to their source (e.g. polyvinyl chloride) and chemicals from toxic wastes (landfill sites) located within 3 km of residence have been associated with NTD in offspring. [39, 40] Some studies have reported negative results for maternal exposures from landfill sites located at distance of over 3 km. [41] Landfill sites contain a range of chemicals which might further contaminate surface and ground water, plants and cattle grown in the vicinity and the air. Maternal exposure to contaminated drinking water with carbon tetrachloride, trichloroethylene, and benzene has been reported to confer an increased risk of NTD and major cardiac defects. [42]

Neural tube defects (NTD)

Neural tube defects occur in over 300,000 newborns annually. [3] Unfortunately we do not have the statistics for these abnormalities in sub-Sahara Africa including Nigeria. Non-syndromic or isolated NTDs result when the neural tube closure fails during embryogenesis. Fundamental questions of molecular and cellular mechanisms of neural tube closure in human embryos remain largely unanswered. [43, 44] The initial step in neural tube development (neurulation) is a characteristic thickening of the ectoderm from the level of the primitive node of Hensen caudally to the prochordal plate rostrally at the beginning of the 3rd week of embryonic life. This slipper-shaped structure is called the neural plate. In humans, neural plate development into the neural tube occurs via a two-step process - primary neurulation (day 21 to 28 of embryogenesis) helps in the formation of the brain and most part of the spinal cord and secondary neurulation (day 35 to 42 of embryogenesis) leads to the formation of the neural tube caudal to the mid-sacral region. [45] Failure of primary neurulation results in open neural tube defects generally seen in anencephaly, myelomeningocele also known as open spina bifida and craniorachischisis. Any deformity in spinal cord structure that are covered by skin are called closed neural tube defects. It ranges from asymptomatic spina bifida occulta to severe spinal cord tethering and is traceable when secondary neurulation is disrupted. [46]

Various clinical presentation of NTD are as follows: Anencephaly – The neural tube fails to get close and presents with absence of large part of the brain, skull, and scalp. Encephaloceles - Cranial contents protrude beyond the normal confines of the skull through a calvarium defect. Myelomeningocele - Failure of spinal neural tube closure, especially in the lumbosacral region. It involves underlying layers that includes the spinal cord, nerve roots, vertebral bodies, meninges and skin. Craniorachischisis - Neural tube closure is completely absent in this disease, which affects both the brain and the spine. Initiating event of neurulation in the early embryo fails, resulting in craniorachischisis. [47] Despite years of intensive epidemiological, clinical and experimental research, the exact etiology of NTD remains rather complex and poorly understood. It is generally agreed that most NTD cases are of multifactorial origin, having a significant genetic component to their etiology that interacts with a number of environmental risk factors. [1, 48] It involves gene–gene, gene–environment and gene–nutrient interactions. [6]

Environmental pollution and Parental occupation: Differential incidence of NTD depending on the geographic areas, socioeconomic status of the parents, seasonal variations, discordance in monozygotic

twinning, etc. point to the possibility of an environmental component to the etiology of NTD. Alternatively, these variations in frequency might point to possible gene–environment interactions at critical stages of neural tube development. A host of physical agents (e.g. X-irradiation, hyperthermia, stress), chemical agents (e.g. organic mercury, lead), air and water pollutants and occupational exposure to environmental teratogens are associated with the development of NTD as shown under 'environmental factors' above.

Hyperthermia: A recent meta-analysis indicates that maternal hyperthermia during gestation is associated with an enhanced incidence of neural tube defects (odds ratio 1.95) showing that the neural tube is heat-sensitive in human embryos too. [49]

IV. Recommendation

There is urgent need for creation of Nigerian national and regional registers of birth defects and formulation of national policies on their management as obtainable in the developed countries of Europe and North America. Given the enormous impact of environmental pollution on the prevalence of birth defects, it is highly recommended that daily air quality check should be carried out in Nigeria or at least in the cities and in the Niger Delta in particular. Furthermore, the Federal Government should ensure that companies including multinationals observe the environmental laws of the land, A dedicated Fetal Medicine unit should be built and fully equipped in each of the Federal Teaching Hospitals in the country. Super centres where fetal surgery can be done is also highly recommended, one in the far North, one in the Middle-Belt, another in the Western and one in the Eastern part of Nigeria. Finally, it is highly recommended that a multi-centre prospective study on the same subject involving all the geopolitical regions of Nigeria be carried out. Attention should be paid to the risk factors for birth defects in each region including physical and laboratory-based human biomonitoring.

V. Conclusion

There is no national or regional register of birth defects or guideline on their management in the Niger Delta. There is also no record of named environmental pollutant as a causative factor of the defects and therefore no nationally or regionally planned strategy on their prophylaxis. Pregnancies in developing countries with the Niger Delta inclusive tend to be exposed to potential environmental teratogens to a higher degree than in industrialized nations and therefore there should be more congenital abnormalities in the developing countries than in the developed world. The causes of birth defects in the Niger Delta are largely not known. The known causes are of genetic and non-genetic origin with environmental factors inclusive. The environmental factors are neglect of environmental protection policies and laws, drinking of contaminated water with heavy metals, chlorinated and aromatic solvents (trichloroethylene, benzene), occupational exposure to environmental teratogens. toxic waste disposal including landfill sites and incineration of the waste and exposure to naturally occurring radioactive materials (NORM).

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