Review Article

An Evaluation of Environmental Contamination on Public Health: A Review of Air Pollution in Nigeria

Abstract

Numerous researchers have recognized environmental contamination as a potential danger to both the ecosystem and the general population's health. However, studies have shown that air pollution is a substantial contributor to a variety of respiratory conditions, including chronic obstructive pulmonary disease (COPD), shortness of breath, respiratory infections, and other similar conditions. To counteract this, however, the formulation and execution of public health policies might be of assistance in the fight against environmental pollution. In this study, the researchers investigated the ways in which air pollution, being a kind of environmental contamination, leads to problems in public health. In light of this, we reviewed the assessment of surveillance and monitoring, the consequences of human exposure to air pollution on public health, the influence of environmental pollution on social behaviors, as well as the ethical and legal implications of environmental contaminations. The study came to the conclusion that it is imperative to initiate possible action, since reducing the amount of air pollutants and chemicals in the environment may assist in avoiding further consequences of environmental degradation as well as limit the amount of harm done to human health. As a result, it is necessary to include monitoring of ambient $PM_{2.5}$ and other air pollutants over a long length of time at a number of places that are typical of important metropolitan activities. These areas include trash dumps, transportation, and manufacturing facilities.

Keywords: Air Pollution, Environment, Contamination, Public Health, Exposure

Introduction

Substantial progress has been made in society and the economy since the mid-20th century. However, current development is characterized by excessive patterns of consumption and uncontrolled urbanization, leading to ecological destruction, climate change, and socioeconomic inequalities. Because of the rapidity and severity of environmental degradation, there have been a variety of unforeseen repercussions on health and well-being, both in the present and in the future. Those who live and/or work in polluted areas are, by far, the most impacted of all the categories. They are vulnerable to a wide range of hazards, such as unregulated waste collection and disposal, air pollution, hazardous chemical exposure, unsanitary living conditions, and forced relocation due to natural disasters (WHO, 2016).

It is common knowledge that the most common cause of environmental sickness is air pollution, which may occur both outside and indoors[90,91,92]. Towns and cities are the primary contributors to poor air quality. More than eighty percent of people who live in cities are often exposed to air pollution, as stated by the World Health Organization (2016). It is important to emphasize the impact that air pollution has on a number of different public health concerns. Even in situations when there seems to be a low level of air pollution, those who are sensitive and prone to health problems may still have health problems. An increased risk of developing chronic obstructive pulmonary disease (COPD), difficulty breathing, infections of the respiratory tract, coughing and wheezing asthma, and high rates of hospitalisation (a measure of morbidity) is clearly associated with even brief exposure to air pollution.

There is a correlation between the effects of prolonged exposure to air pollution and the development of health issues such as chronic asthma, cardiovascular illnesses, pulmonary insufficiency, and cardiovascular mortality (Manisalidis *et al*., 2020). Environmental pollutants that are hazardous to people's health include all of these adverse consequences of air pollution, which are examples of environmental pollutants. According to the findings of a Swedish cohort study (Manisalidis *et al*., 2020), being exposed to air pollution for a lengthy period of time seems to be a risk factor for acquiring diabetes. Furthermore, according to Kellishadi and Poursafa (2018), air pollution seems to have a variety of adverse consequences on the health of younger people, including challenges in the areas of respiratory, mental, cardiovascular, and perinatal health development. These issues may cause long-term health problems in adults or possibly the infant's death.

Soil and surface water nutritional quality may be negatively impacted by air pollution, according to Kjellstrom *et al*. (2017). This is because air pollution makes polluting precipitation to fall into these habitats, which in turn degrades the soil's nutritional condition. Acid precipitation may have an effect on plants, cultures, and the quality of water, which can lead to changes in the chemistry of the soil (Pathak *et al*., 2011). Acidity in the soil also facilitates heavy metal mobility, which in turn causes metals to be transported into aquatic ecosystems more, while heavy metals like aluminum are bad for fish and other animals, and may be more harmful for humans if it gets in contact with consumables. As a result of the fact that soils with low calcium carbonate levels are often more susceptible to acid rain, the quality of the soil seems to be quite important. Not only does rain fall into aquatic bodies, but snow and particle debris also fall into these bodies (Kjellstrom *et al*., 2017; Bonavigo *et al*., 2009).

Consequences of Air Pollution on Public Health

The emphasis of this research was on air pollution, and it investigated the ways in which environmental hazards impact public health. As a result of the fact that poor air quality is becoming an increasingly important problem in the framework of sustainable development, particularly in relation to health in urban and metropolitan areas, efforts coming from a variety of sectors are required to improve air quality. For a number of reasons, including the economy, worker productivity, the cost of healthcare for the present generation and the generations to come, and tourism, air pollution is a barrier to the sustainable growth of the country (Ucheje *et al*., 2024). When it comes to protecting the health of the general people, the improvement of air quality is of key importance.

Environmental factors, biodiversity, ecosystem services, and food security may all benefit from cleaner air, as opined by the World Bank Group (2018). According to Mannucci and Franchini (2017), several countries, including Nigeria, have recognized air pollution as a serious environmental problem. This is especially true in developing nations. With an estimated population of more than 200 million people, Nigeria is the most populous country on the African continent (Echendu, 2020a). As the most populous nation in Africa, air pollution is only one of the many environmental problems that the nation is now dealing with. The air quality in its major cities, including as Lagos, Port Harcourt, and others, is among the worst in the world (Okon, 2019). According to Adekola and Mitchell (2011) ; Babatunde (2020), the Niger Delta area of Nigeria is the economic core of the nation; nevertheless, it is also one of the least developed regions and has worsened due to environmental degradation.

According to research and policy papers published by the government of Nigeria (Whyte *et al*., 2020; Urhie *et al*., 2017; Urhie *et al*., 2020; Usman *et al*., 2019), air pollution has a negative impact on human health in Nigeria. However, it has a less significant impact on the health of ecosystems and climate change. There is need for more information to substantiate the notion that persons exposed to elevated levels of pollution in the air experience different levels of sickness symptoms and conditions. There are two categories of these effects: those that have an immediate impact on health and persons that have long-term impact. According to Manisalidis *et al*.'s research in 2020, vulnerable populations that should be informed about health-protection measures include persons who are diabetics, children, elderly, and those who are at a greater risk of developing lung diseases or heart issues especially asthma.

In addition, according to the findings of an epidemiological study conducted by the Harvard School of Public Health, it has been difficult to ascertain the precise magnitudes of the short-term and long-term effects due to the fact that exposure errors and different epidemiological methodologies have been used. In order to better the accuracy of data collected on both short-term and long-term human exposure (Kloog *et al*., 2013). In their study, they recommended updating to more current models. Concerns about both the short-term and long-term health impacts are prevalent since they depend on factors such as the environment, dosage, and the person's susceptibility, even as Manisalidis *et al*. (2020) noted that the former are more widely acknowledged. The immediate effects might range from mild irritation (sore throat, eyes, nose, or skin) to more serious health problems (asthma, bronchitis, pneumonia, heart problems, lung problems, etc.).

Other symptoms that may be present include wheezing, chest tightness, and difficulty in breathing. Additionally, after a brief exposure to air pollution, one may experience symptoms such as headaches, nausea, and symptoms of disorientation (Manisalidis *et al*., 2020; Nakano and Otsuki, 2013). As stated by Manisalidis *et al*. (2020) and Nakano and Otsuki (2013), prolonged exposure to pollutants may compound these problems and cause damage to the brain system, respiratory system, and reproductive system, which can ultimately result in the development of cancer and even death in certain cases. It is also possible that these effects will have a negative influence on the immune system. On the other hand, the long-term consequences may be deadly, they may continue for years or even a lifetime, and they are chronic. In addition, certain air contaminants are hazardous and may cause malignancies of different kinds if left unchecked for a longer period of time (Nakano and Otsuki, 2013).

Evaluation of Surveillance and Monitoring

Air pollution in general is associated with a major issue in public health. The most strongly linked air pollutants to adverse human health impacts are sulfur dioxide, particulate matter, nitrogen dioxide, and ozone (World Health Organization, 2006). Particulate matter with a diameter of less than 2.5 micrometers ($PM_{2.5}$) is the most significant determinant of urban air quality, according to Cohen *et al*. (2005). Around 2.9 million people died too soon in 2017 due to ambient $PM_{2.5}$ pollution, which is about 9 percent of all deaths worldwide, as reported in the 2017 Global Burden of Diseases study.

According to the report, approximately 150,800 people in Sub-Saharan Africa lost their lives to air pollution the same year. Nigeria as a nation is an area with the largest number of early deaths caused by ambient $PM_{2.5}$ pollutant, therefore this issue affects them greatly (International Health Monitoring Organization, 2018). Nigeria has a much higher risk of premature mortality from ambient $PM_{2.5}$ pollution (23.8 per 100,000 people) compared to other countries in Sub-Saharan Africa (14.7 per 100,000 individuals), according to the International Health Monitoring Organisation (2018). However, it has been estimated that Lagos city of Nigeria by 2100 will be recorded as one of the most populated cities globally (Hoornweg and Pope, 2016). But most people on earth are already breathing in dangerously high amounts of air pollutants caused by rising industries and urbanization (Olowoporoku *et al*., 2012; Orisaleye *et al*., 2018).

The research by Ucheje and Okolo (2023); Ucheje *et al*. (2022) which showed that between 2016 and 2018, the average concentration of air pollutants rose across all locations studied, in Port Harcourt, Nigeria, was similar to the above study. The most likely explanations for the fluctuation were changes in the weather and a steady increase in the amount of traffic on the roads. The ambient $PM_{2.5}$ concentration in Lagos has changed over time, according to an analysis of the most recent research. Results showed that $PM_{2.5}$ concentrations may range from 12 g/m3 to 85 g/m3 depending on testing conditions such as time of day, location, and season (for further details, see figure 1).

Notably, Etchie *et al*. (2018) used satellite data in their study without doing any ground-level calibration. Several additional studies have also used air samplers to gather data on $PM_{2.5}$ for brief durations, often less than three months (Alani *et al*., 2019; Obanya *et al*., 2018; Obioh *et al*., 2013). It was unacceptable to use these attempts to determine the average annual $PM_{2.5}$ concentration in Lagos because of how diverse they were (Owoade et al., 2013; Ezeh *et al*., 2018)—collected data over long durations. The first research gathered data in four distinct places every two weeks for nine months (February 2010–October 2010), while the second study gathered data in three different sites every week for a year (December 2010–November 2011). The research estimated the population-weighted $PM_{2.5}$ concentration for the city of Lagos using the data from the latter. The reason for this was the increased frequency and duration of recording the $PM_{2.5}$ concentration and was calculated it to be 68 g/cm².

The following considerations suggested that the previously indicated pollution estimate is cautious: First, it is based on data collected in 2010 and 2011. Second, since then, air pollution has probably increased due to rising traffic and economic activity. This estimated amount was much higher than the World Health Organization's recommended guideline value of 10 g/m3, notwithstanding the precautions mentioned earlier (WHO, 2006). Comparing it to other highly polluted major cities like Cairo and Beijing, it is likewise within a comparable range (See figure 2). This is a discovery that was not anticipated.

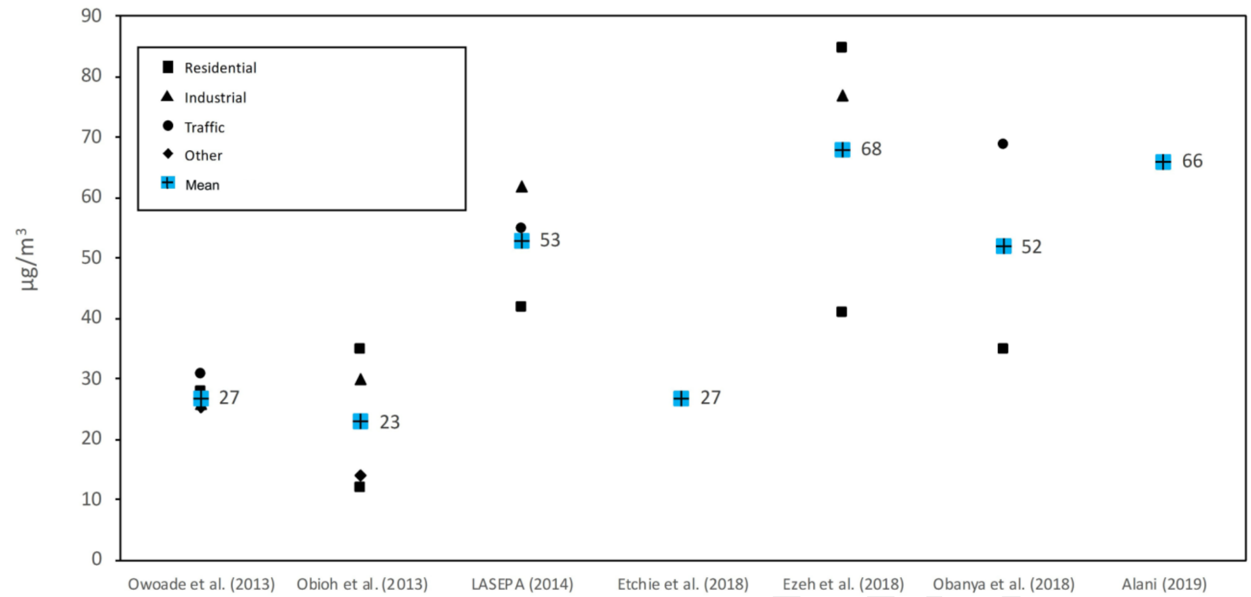

Figure 1: The ambient PM2.5 concentration in Lagos has been estimated by many research studies. Ezeh et al. (2018), Etchie et al. (2018), Obanya et al. (2018), Alani et al. (2017), and Croitoru et al. (2017),Obioh et al. (2013), and Owoade et al. (2013)are many sources that provide evidence in favor of this assertion. The data provided by Etchie et al. (2018) is derived from satellite measurements, and the remaining data is collected by ground-level observations. The statistic only encompasses the findings of research that monitored $PM_{2.5}$ levels for a duration exceeding one month. The mean values for the other research are calculated using arithmetic means, however for Ezeh et al. (2018), they represent a population-weighted average.

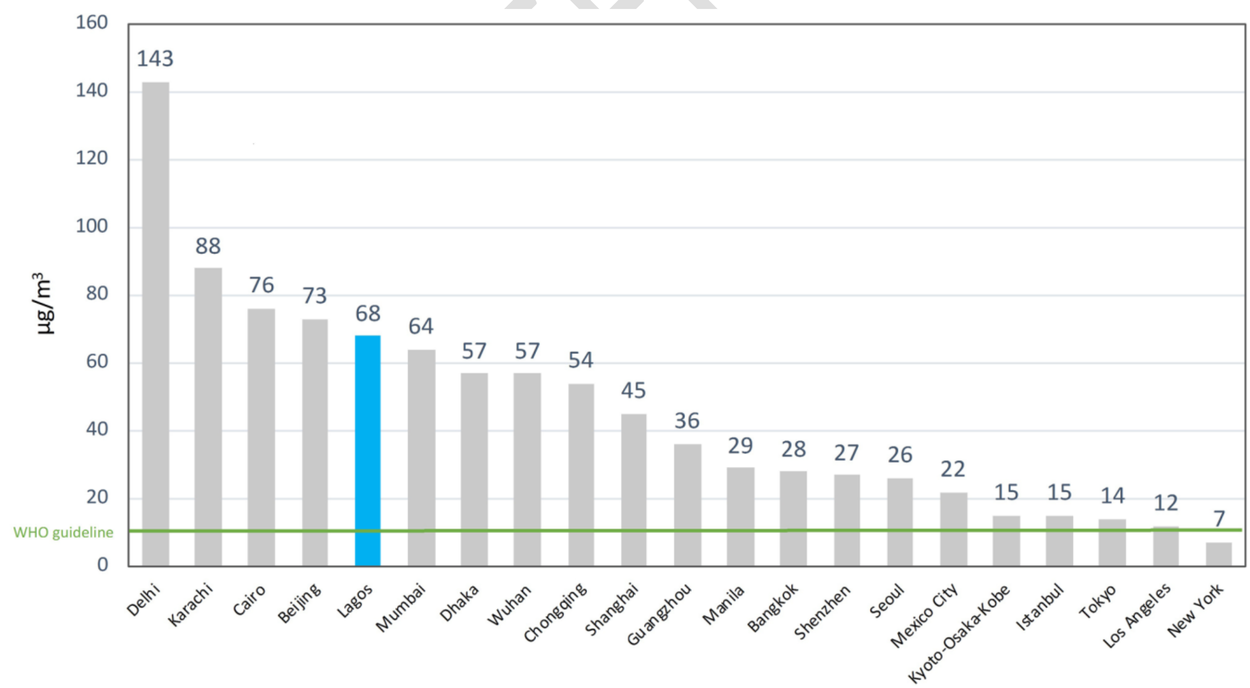

Figure 2: Annual average concentration of PM2.5 in many large cities. References: The World Health Organization (WHO) provided information for other cities in 2016 and 2018. The study conducted by Croitoru et al. in 2020 specifically focused on Lagos.

Inadequate waste management as a result of open landfills and unlawful burning of rubbish (Adegboye, 2018), as well as the use of power generators (Oseni, 2016; Cervigni *et al*., 2013), are the primary contributors to the high concentration of $PM_{2.5}$ in Lagos. The building industry is one of the main contributors to this problem (Adama, 2018). Two natural sources that are acknowledged as substantial by Marais *et al*. (2019) include dust and sea salts.

The year 2010 was the year when Owoade *et al*. (2013) carried out major component factor analysis. They observed three distinct places, each of which represented a different kind of environment: residential, urban, or maritime. According to the findings, the presence of a large volume of vehicle traffic had a significant influence on the concentration of particulate matter 2.5 in residential areas. The industry itself was the primary contributor to the concentration of $PM_{2.5}$ in industrial regions, followed by transportation as the second most significant source. In addition, Ezeh *et al*. (2018) conducted a positive matrix factorization study which made use of $PM_{2.5}$ data obtained from three different sites between the years 2010 and 2011. Neighborhoods with varying densities of residents, as well as business areas, were among these spots. According to the authors, 70% of the entire mass load of $PM_{2.5}$ is caused by the combustion of petroleum, which comes from gasoline-powered cars and generators. Vehicle traffic, emissions from industrial facilities, and power generation are the key contributors to the existence of $PM_{2.5}$ pollution in Lagos, according to the studies, which have often demonstrated that these are the primary culprits.

Effects of Human Exposure to Air Pollution on Public Health

Three epidemiological studies; Apte *et al*. (2015), Soriano *et al*. (2020), and Wu *et al*. (2020) have shown that long-term exposure to $PM_{2.5}$ is directly associated with premature mortality in people of all ages. Exposure to this substance increases the risk of lung cancer, lower respiratory infections, stroke, ischemic heart disease, type 2 diabetes mellitus, tracheal and chronic bronchitis, and bronchus illnesses, among many other health complications. Using specific relative risk variables, the Global Burden of Illness research attempted to ascertain what percentage of deaths may be rooted in $PM_{2.5}$. These variables were based on (i) mortality rates by illness and age group, as well as (ii) data about sickness, age, and $PM_{2.5}$ concentration information (GBD, 2018). Using these statistics, one may determine the effect that $PM_{2.5}$ pollution has on premature death.

Approximately 11,200 fatalities that might have been avoided occurred in Lagos in 2018 as a result of the inhalation of $PM_{2.5}$ particles that were present in the environment, according to the findings of the study. Children under the age of five are the most susceptible group, accounting for approximately sixty percent of all fatalities (refer to figure 3). Lower respiratory infections are the major cause of mortality which is a consequence of exposure to $PM_{2.5}$. Research from the Global Burden of Disease project lends credence to this idea, showing that ambient $PM_{2.5}$ is a major contributor to Nigeria's overall mortality rate. From this vantage point, it is critical to note that, when all risks, including air pollution, are included, Nigeria has the second-lowest prevalence of respiratory illnesses worldwide and the highest death rate among children under the age of five in Africa. The study on the Global Burden of Disease (GBD) 2018 is the source of this information.

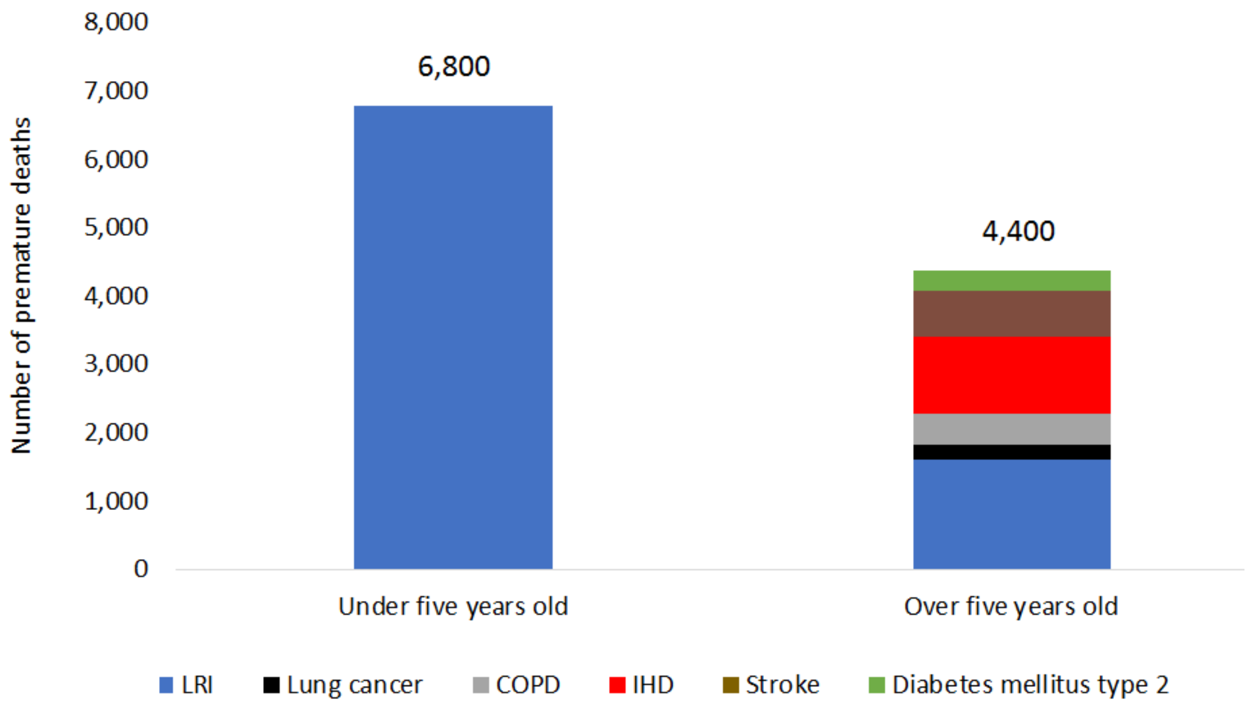

Figure 3: Projected mortality rate in Lagos, Nigeria, in 2018 due to ambient $PM_{2.5}$ pollution. According to Croitoru *et al*. (2020), the writers. Definitions: LRI is an abbreviation for lower respiratory infections, IHD stands for ischemic heart disease, and COPD refers to chronic obstructive pulmonary disease.

Effect of Environmental Pollution on Social Behaviors

Various levels of exposure to ambient air pollution exist, which may contribute to the exacerbation of socioeconomic and racial-ethnic inequality. According to Tessum *et al*. (2019), ambient air pollution is widespread, meaning that it affects individuals of all ages and from all different sections of the world. According to Landrigan (2017), the enormous impact that it has on public health is a result of a number of factors, including urbanization, the rising prevalence of industrial activity on a global scale, and the use of cars powered by internal combustion engines. Poglaan *et al*. (2019), Raz *et al*. (2018), Ritz *et al*. (2018), and Volk *et al*. (2013) are among the growing number of studies that point to ambient air pollution as a potential factor influencing neurological function and social-neurobehavioral outcomes, including autistic spectrum disorders.

Prolonged exposure to air pollution increases the likelihood of developing respiratory and cardiovascular diseases and their complications, as well as their death, according to research by Cohen *et al*. (2017). Polluted air may cause neurodevelopmental and neuropsychiatric symptoms in rats, according to animal models that have corroborated epidemiologic data (Costa *et al*., 2020; Cory-Slechta *et al*., 2019; Allen *et al*., 2017). Experimental study provided the basis for these results. It follows that if low-level exposure to air pollution may affect the occurrence or severity of certain illnesses, then how else might air pollutants influence society as a whole? Considering the impact it might have on animal culture as well as human society, this is probably a major concern.

Experimental studies investigating the effects of air pollution on social behaviors and decision-making are few. There is evidence linking air pollution to an uptick in aggressive behavior in humans (Lu *et al*., 2018; Mielke and Zahran, 2012), as well as a decline in social skill (the ability to regulate one's relationships with others) (Margolis *et al*., 2016). Air pollution has been associated with both of these results. According to O'Connell and Hofmann (2011), social behavior is defined as interactions between many human/animals when one species influences the other. These encounters may happen between different kinds of animals. This effect often manifests itself when individuals of the same species interact with one another.

Flocking, swarming, and schooling are only a few examples of the many group behaviors that exist. This might include things like sexual activity, partner selection, couple bonding, hostility, cooperation, and parental care. This category may also include other activities, many of which are dyadic. The crucial role of hormones in influencing behavior has led to studies on other environmental pollutants and their potential effects, such as endocrine disrupting chemicals (such as those that impede hormones and their actions), in a range of taxa since the 1970s (Gore *et al*., 2019; Vom Saal *et al*., 2012). To learn more about how these contaminants influence behavior, researchers have undertaken several investigations. According to Gore *et al*., (2019), the findings of this study shed light on the many ways in which chemical exposures in the environment might alter people's social behaviors. This is especially the case when exposures occur at highly malleable stages of development. Hence, the relevance of these exposures was seen from the works of the above scholar.

Despite the abundance of literature on topical and oral sources, Annamalai and Namasivayam (2015); Darbre (2018) argued that air pollution is a major endocrine-altering exposure modality. Inhalation is a very efficient route of exposure for neurological effects due to the fact that substances may bypass the blood-brain barrier and enter the brain directly. Reason being, chemicals are capable of immediately penetrating the brain. It is feasible to identify endocrine-disrupting chemicals in the air, whether they are gases or particulate matter (Darbre, 2018). There may be non-endocrine mechanisms by which air pollution influences social behavior (Jayaraj *et al*., 2017). Direct neuronal injury, oxidative stress, and neuroinflammation are some of these ways. This is so even when there are a wide variety of air pollutants.

Furthermore, a particular meta-analysis and systematic review indicated that while short-term exposure to ozone, particulate matter, sulfur dioxide, and nitrogen dioxide did not correlate with any health effects, there was a positive correlation between these pollutants and depression (Braithwaite *et al.*, 2019). Additional meta-analysis by Braithwaite *et al*. (2019) indicated that exposure to fine particulate matter for more than six months is associated with depression. These studies effectively highlighted the gaps in knowledge and emphasized the need for further research to fill them in order to answer the question of how much air pollution affects mental health outcomes.

Ethical and Legal Implications of Environmental Contaminations

Ensuring the safety of underprivileged communities against environmental hazards has its foundation in the principle of distributive justice (Shrader-Frechette, 2012; Resnik, 2012; Cranor, 2008a; 2008b; 2008c). In light of the fact that health has an effect on opportunities, financial resources, and other resources, policies that investigate the manner in which environmental health threats are dispersed raise concerns of justice (Daniels, 2008). Fair distribution of environmental health hazards requires a decision-making process that lawfully and appropriately balances competing interests and objectives (Cranor and Finkel, 2016). This is necessary in order to achieve equity.

According to Ferrey (2016), residents who live in close proximity to a facility that emits air pollution that is detrimental to their health have the ability to file a private or public nuisance claim against the corporate entity. In these kinds of circumstances, the tort system decides what kinds of actions that are harmful to the environment are recognized to be types of "damage." This might help stop future rights abuses since individuals generally change their ways to stay out of trouble with the law. Those who want environmental liability cases resolved by the common law often also acknowledge the need to modify tort law (Adler, 2009; 2012).

The current corpus of case law fails to provide the precedents required to competently defend individual and property rights pertaining to environmental issues. Tort law's failure to compel emissions demonstrates how inadequately the law safeguards individuals' rights to their property and persons. It may be very challenging to establish a causal link between actions that cause air pollution and subsequent injuries sustained as a result of those actions in a tort complaint against an air polluter. When air pollution is generated, it is usually because millions of people contribute to such generation, rather than just an individual polluter. The scenario becomes much more complex due to this fact. According to Resnik *et al*. (2018), harmed parties can lack the financial means to win a case against pollutants, even if a causal link can be shown. The ability to establish a causal relationship does not change this fact. Therefore, in order to safeguard the health of the populace, it is necessary to take into account the ethical and legal implications of each and every environmental activity.

Recommendations

It is essential to find development solutions that are less harmful to the environment in order to solve environmental issues and offer a green environment that is sustainable. It is possible to achieve this goal via the use of clean and renewable energy sources, as well as through the improvement of education and knowledge of the current terrible status of the environment, especially in Nigeria (Wambebe and Xiaoli, 2021). The United Nations thinks that the actions taken to achieve one goal will have an effect on the results for other objectives, and they believe that this will be the case via the integration of the Sustainable Development objectives. It is also possible to approach the issue of environmental pollution from the perspective of human rights, whereby the act of polluting the environment would constitute a violation of such rights. This is in line with the objectives of the United Nations as well as regional environmental treaties such as the African Charter on Human and Peoples' Rights. "The failure of governments all over the globe to protect clean air amounts to an infringement of one's rights to life, wellness, and health, as well as to the right to live in a healthy environment" (UN, 2019), according to an impartial UN expert.

Conclusion

There is a need to address environmental pollutants in Nigeria, such as pollution in the air. Motor vehicle traffic, industrial activity, and the generation of energy are the primary source of pollution in the atmosphere, including particulate matter ($PM_{2.5}$) and sulfur dioxide (SO_2). It is imperative that prompt action be done since reducing the amount of air pollutants and chemicals in the environment may avoid subsequent repercussions of environmental degradation in addition to limiting the harmful effects on human health. According to Croitoru *et al*. (2020), considering the use of solar power cells in conjunction with batteries as a means of storing energy for the purpose of generating electricity is one of the potential possibilities that have to be researched. The completion of inspections of vehicles, the modernization of the vehicles that produce the greatest pollution, the adaptation of cleaner fuel, and the provision of financial incentives to consumers who purchase cleaner passenger automobiles are some of the other measures.

Air pollution is a major problem in Nigerian cities, endangering the health of people of all ages and socioeconomic backgrounds. Engaging in a single action would not be able to fix this problem. The goal and objective of the World Bank's PMEH/AQM project is to develop a scientifically sound strategy to reduce air pollution that accounts for measures in the industries that are responsible for the majority of contamination. One of the aims for future study is to monitor ambient $PM_{2.5}$ levels over a long period of time at several sites that reflect important urban activities such as traffic, industry, and garbage dumps. Also, gathering a list of the emissions of air pollutants along important roadways, such as particulate matter, SO_X, and NO_X, for a longer period of time in urban milieus should be a priority.

References

1. Adama, O. (2018) Urban Imaginaries: Funding Mega Infrastructure Projects in Lagos, Nigeria. *GeoJournal*, **83**, pp. 257-274.
2. Adegboye, K. (2018) Why Problem of Waste Management Persists in Lagos. Vanguard. Available from: https://www.vanguardngr.com/2018/10/why-problem-of-waste-management-persis ts-in-lagos-stakeholders [Accessed 21st March 2023]
3. Adekola, O. and Mitchell, G. (2011). The Niger Delta wetlands: Threats to ecosystem services, their importance to dependent communities and possible management measures. *International Journal of Biodiversity Science Ecosystem Services & Management*. **7**, pp. 50–68.
4. Adler, J.H. (2009) Taking property rights seriously: The case of climate change. *Social Philosophy and Policy*. **26**(2), pp. 296–316
5. Adler, J.H. (2012) Is the common law a free-market solution to pollution? *Critical Review*. **24**(1), pp. 61–85.
6. Alani, R. (2019) $PM_{2.5}$ Data Measured during November 2018-March 2019 (Unpublished, Communication with the World Bank).
7. Alani, R.A., Ayejuyo, O.O., Akinrinade, O.E., Badmus, G.O., Festus, C.J. and Ogunnaike, B.A. (2019) The Level $PM_{2.5}$ and the Elemental Compositions of Some Potential Receptor Locations in Lagos, Nigeria. *Air Quality, Atmosphere & Health*, **12**, pp. 1251-1258
8. Allen, J.L., Oberdorster, G., Morris-Schaffer, K., Wong, C., Klocke, C. and Sobolewski, M. (2017). Developmental neurotoxicity of inhaled ambient ultrafine particle air pollution: Parallels with neuropathological and behavioral features of autism and other neurodevelopmental disorders. *Neurotoxicology*. **59**, pp. 140–154.
9. Annamalai, J. and Namasivayam, V. (2015) Endocrine disrupting chemicals in the atmosphere: their effects on humans and wildlife. *Environ Int*. **76**, pp. 78–97.
10. Apte, J.S., Marshall, J.D., Cohen, A.J. and Brauer, M. (2015) Addressing Global Mortality from Ambient $PM_{2.5}$. *Environmental Science and Technology*, **49**, pp. 8057-8066.
11. Babatunde, A. O. (2020). Oil pollution and water conflicts in the riverine communities in Nigeria's Niger Delta region: Challenges for and elements of problem-solving strategies. *Journal of Contemporary African Studies*. **38**, pp. 274–93
12. Block, M.L., Elder, A., Auten, R.L., Bilbo, S.D, Chen, H.L. and Chen, J.C. (2012) The outdoor air pollution and brain health workshop. *Neurotoxicology*. **33**(5) pp. 972–984.
13. Bonavigo, L., Zucchetti, M. and Mankolli, H. (2009) Water radioactive pollution and related environmental aspects. *J Int Env Appl Sci*. **4**, pp. 357–363
14. Braithwaite, I., Zhang, S., Kirkbride, J.B., Osborn, D.P.J. and Hayes, J.F. (2019) Air pollution (particulate matter) exposure and associations with depression, anxiety, bipolar, psychosis and suicide risk: a systematic review and meta-analysis. *Environ Health Persp*. **127**(12), pp. 1-11

15. Cervigni, R., Rogers, J.A. and Dvorak, I. (2013) *Assessing Low-Carbon Development in Nigeria: An Analysis of Four Sectors*. World Bank, Washington DC.
16. Cohen, A.J., Anderson, H.R., Ostro, B., Pandey, K.D., Krzyzanowski, M. and Künzli, N. (2005) The Global Burden of Disease Due to Outdoor Air Pollution. *Journal of Toxicology and Environmental Health, Part A*, **68**, pp. 1301-1307.
17. Cohen, A.J., Brauer, M., Burnett, R., Anderson, H.R., Frostad, J. and Estep, K. (2017) Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *Lancet*. **389**(10082), pp. 1907–1918
18. Cory-Slechta, D.A., Sobolewski, M., Marvin, E., Conrad, K., Merrill, A. and Anderson, T. (2019) The impact of inhaled ambient ultrafine particulate matter on developing brain: potential importance of elemental contaminants. *Toxicol Pathol*. **47**(8), pp. 976–992
19. Costa, L.G., Cole, T.B., Dao, K., Chang, Y-C., Coburn, J. and Garrick, J.M. (2020) Effects of air pollution on the nervous system and its possible role in neurodevelopmental and neurodegenerative disorders. *Pharmacol Therapeut.* **210**, pp. 1-12
20. Cranor, C.F. (2008a) (Almost) equal protection for genetically susceptible subpopulations: A hybrid regulatory compensatory model. In: Sharp, RR.Marchant, GE., Godsky, JA., editors. *Genomics and environmental regulation*. Baltimore, MD: Johns Hopkins University Press; 2008a. p. 267-89.
21. Cranor, C.F. (2008b) Risk assessment, susceptible subpopulations and environmental justice. In: Gerrard, MB., Foster, S., editors. *The law of environmental justice: theories and procedures to address disproportionate risk*. 2. Chicago, IL: American Bar Association; 2008b. p. 341-94.
22. Cranor, C.F. (2008c) *Toxic torts: science, law and the possibility of justice*. Cambridge, UK: Cambridge University Press.
23. Cranor, C.F. and Finkel, A.M. (2016) *Toward the usable recognition of individual benefits and costs in regulatory analysis and governance*. Regulation and Governance.
24. Croitoru, L., Chang, J.C. and Kelly, A. (2020) *The Cost of Air Pollution in Lagos*. The World Bank, Washington DC.
25. Daniels, N. (2008) *Just health: Meeting health needs fairly*. Cambridge, UK: Cambridge University Press.
26. Darbre, P.D. (2018) Overview of air pollution and endocrine disorders. *Int J Gen Med*. **11**, pp. 191–207
27. Echendu, A. J. (2022a). Flooding, Food Security and the Sustainable Development Goals in Nigeria: An Assemblage and Systems Thinking Approach. *Social Sciences* **11**(59), pp. 1-14
28. Etchie, T.O., Etchie, A.T., Adewuyi, G.O., Pillarisetti, A., Sivanesan, S. and Krishnamurthi, K. (2018) The Gains in Life Expectancy by Ambient $PM_{2.5}$ Pollution Reductions in Localities in Nigeria. *Environmental Pollution*, **236**, pp. 146-157.

29. Eze, I.C., Schaffner, E., Fischer, E., Schikowski, T., Adam, M., Imboden, M., Tsai, M., Carballo, D., von Eckardstein, A., Künzli, N., Schindler, C. and Probst-Hensch, N. (2014) Long- term air pollution exposure and diabetes in a population-based Swiss cohort. *Environ Int*. **70** pp. 95-105
30. Ezeh, G.C., Obioh, I.B., Asubiojo, O.I., Onwudiegwu, C.A., Nuviadenu, C.K. and Ayinla, S.B. (2018) Airborne Fine Particulate Matter ($PM_{2.5}$) at Industrial, High and Low-Density Residential Sites in a Nigerian Megacity. *Toxicological & Environmental Chemistry*, **100**, pp. 326-333.
31. Fan, S-J., Heinrich, J., Bloom, M.S., Zhao, T-Y., Shi, T-X. and Feng, W-R. (2020) Ambient air pollution and depression: a systematic review with meta-analysis up to 2019. *Sci Total Environ*. **701**, pp. 1-12
32. Ferrey, S. (2016) *Environmental law*. 7. New York, NY: Wolters Kluwer.
33. GBD (2017) Risk Factor Collaborators (2018) Global, Regional, and National Comparative Risk Assessment of 84 Behavioural, Environmental and Occupational, and Metabolic Risks or Clusters of Risks for 195 Countries and Territories, 1990-2017: A Systematic Analysis for the Global Burden of Disease Stu. *The Lancet*, **392**, pp. 1923-1994.
34. Genc, S., Zadeoglulari, Z., Fuss, S.H. and Genc, K. (2012) The adverse effects of air pollution on the nervous system. *J Toxicol*. **2012**(782462), pp. 1-13
35. Gore, A.C., Krishnan, K. and Reilly, M.P. (2019) Endocrine-disrupting chemicals: Effects on neuroendocrine systems and the neurobiology of social behavior. *Horm Behav*. **111**, pp. 7–22
36. Hoornweg, D. and Pope, K. (2016) Population Predictions for the World's Largest Cities in the 21st Century. *Environment and Urbanization*, **29**, pp. 195-216.
37. Ibitayo, O.O. (2012) Towards Effective Urban Transportation System in Lagos, Nigeria: Commuters' Opinions and Experiences. *Transport Policy*, **24**, pp. 141-147.
38. Institute for Health Metrics and Evaluation (IHME) (2018), *Global Burden Disease (GBD) Compare*. Available from: https://vizhub.healthdata.org/gbd-compare/ [Accessed 18 April 2023]
39. Jayaraj, R.L., Rodriguez, E.A., Wang, Y. and Block, M.L. (2017) Outdoor ambient air pollution and neurodegenerative diseases: the neuroinflammation hypothesis. *Curr Environ Health Rep*. **4**(2), pp. 166–179
40. Kelishadi, R. and Poursafa, P. (2018) Air pollution and non-respiratory health hazards for children. *Arch Med Sci*. **6** pp. 483–495
41. Khan, A., Plana-Ripoll, O., Antonsen, S., Brandt, J., Geels, C. and Landecker, H. (2019) Environmental pollution is associated with increased risk of psychiatric disorders in the US and Denmark. *Plos Biol*. **17**(8), 1-14
42. Kjellstrom, T., Lodh, M., McMichael, T., Ranmuthugala, G., Shrestha, R. and Kingsland, S. (2017) Air and Water Pollution: Burden and Strategies for Control. DCP, Chapter 43.

817–32 p. Available online at: https://www.dcp-3.org/sites/default/files/ dcp2/DCP43 [Accessed April 20, 2023]

43. Kloog, I., Ridgway, B., Koutrakis, P., Coull, B.A. and Schwartz, J.D. (2013) Long- and short term exposure to $PM_{2.5}$ and mortality using novel exposure models, *Epidemiology*. **24**, pp. 555–561
44. Landrigan, P.J. (2017) Air pollution and health. *Lancet Public Health*. **2**(1), pp. 4–5.
45. Lim, Y-H., Kim, H., Kim, J.H., Bae, S., Park, H.Y. and Hong, Y-C. (2012) Air pollution and symptoms of depression in elderly adults. *Environ Health Persp*. **120**(7), pp.1023–1028
46. Lu, J.G., Lee, J.J., Gino, F. and Galinsky, A.D. (2018) Polluted morality: air pollution predicts criminal activity and unethical behavior. *Psychol Sci*. **29**(3), pp. 340–355.
47. Manisalidis, I., Stavropoulou, E., Stavropoulos, A. and Bezirtzoglou, E. (2020) Environmental and Health Impacts of Air Pollution: A Review. *Front. Public Health* **8**(14) pp. 1-13
48. Mannucci, P. M. and Franchini, M. (2017). Health effects of ambient air pollution in developing countries. *International Journal of Environmental Research and Public Health* **14** pp. 1048.
49. Marais, E.A., Silvern, R.F., Vodonos, A., Dupin, E., Bockarie, A.S. and Mickley, L.J. (2019) Air Quality and Health Impact of Future Fossil Fuel Use for Electricity Generation and Transport in Africa. *Environmental Science & Technology*, **53**, pp. 13524-13534.
50. Margolis, A.E., Herbstman, J.B., Davis, K.S., Thomas, V.K., Tang, D. and Wang, Y. (2016) Longitudinal effects of prenatal exposure to air pollutants on self-regulatory capacities and social competence. *J Child Psychol Psychiatry*. **57**(7), pp. 851–860
51. Mielke, H.W. and Zahran, S. (2012) The urban rise and fall of air lead (Pb) and the latent surge and retreat of societal violence. *Environ Int*. **43**, pp. 48–55.
52. Nakano, T. and Otsuki, T. (2013) Environmental air pollutants and the risk of cancer. (Japanese). *Gan To Kagaku Ryoho*. **40**, pp. 1441–1445.
53. O'Connell, L.A. and Hofmann, H.A. (2011) Genes, hormones, and circuits: An integrative approach to study the evolution of social behavior. *Front Neuroendocrin*. **32**(3), pp. 320–335
54. Obanya, H.E., Nnamdi, H. and Togunde, O. (2018) Air Pollution Monitoring around Residential and Transportation Sector Locations in Lagos Mainland. *Journal of Health & Pollution*, **8**, pp. 1-10.
55. Obioh, I.B., Ezeh, G.C., Abiye, O.E., Alpha, A., Ojo, E.O. and Ganiyu, A.K. (2013) Atmospheric Particulate Matter in Nigerian Megacities. *Toxicological and Environmental Chemistry*, **95**, pp. 379-385.
56. Okon, E. O. (2019). Exposure to Particulate Matter Air Pollution in Nigeria: Empirical Investigation. *Asian Research Journal of Current Science*. **1**, pp. 27–33.

57. Olowoporoku, A.O., Longhurst, J.W.S. and Barnes, J.H. (2012) Framing Air Pollution as a Major Health Risk in Lagos, Nigeria. *WIT Transactions on Ecology and the Environment*, **157**, pp. 479-488.
58. Orisaleye, J., Ope, A., Busari, O. and Adefuye, O. (2018) Environmental and Health Effects of Industrial and Vehicular Emissions in Lagos, Nigeria. *International Journal of Engineering*, **16**, pp. 225-230.
59. Oseni, M.O. (2016) Get Rid of It: To What Extent Might Improved Reliability Reduce Self-Generation in Nigeria? *Energy Policy*, **93**, pp. 246-254.
60. Owoade, O.K., Fawole, O.G., Olise, F.S., Ogundele, L.T., Olaniyi, H.B. and Almeida, M.S. (2013) Characterization and Source Identification of Airborne Particulate Loadings at Receptor Site-Classes of Lagos Mega-City, Nigeria. *Journal of the Air and Waste Management Association*, **63**, pp. 1026-1035.
61. Pagalan L, Bickford C, Weikum, W., Lanphear, B., Brauer, M. and Lanphear, N. (2019) Association of prenatal exposure to air pollution with autism spectrum disorder. *JAMA Pediatr*. **173**(1), pp. 86–92.
62. Pathak, R.K., Wang, T., Ho, K.F. and Lee, S.C. (2011) Characteristics of summertime $PM_{2.5}$ organic and elemental carbon in four major Chinese cities: implications of high acidity for water- soluble organic carbon (WSOC). *Atmos Environ*. **45**, pp. 318–325.
63. Peeples, L. (2020) News Feature: How Air Pollution Threatens Brain Health. *Proceedings of the National Academy of Sciences*, **117**, pp. 13856-13860.
64. Raz, R., Levine, H., Pinto, O., Broday, D.M., Yuval, R. and Weisskopf, MG. (2018) Traffic-related air pollution and autism spectrum disorder: a population-based nested case-control study in Israel. *Am J Epidemiol*. **187**(4), pp.717–725
65. Resnik, D.B. (2012) *Environmental health ethics*. Cambridge, UK: Cambridge University Press.
66. Resnik, D.B., MacDougall, D.R. and Smith, E.M. (2018) Ethical Dilemmas in Protecting Susceptible Subpopulations from Environmental Health Risks: Liberty, Utility, Fairness, and Accountability for Reasonableness. *Am J Bioeth*. **18**(3), pp. 29–41
67. Ritz, B., Liew, Z., Yan, Q., Cui, X., Virk, J. and Ketzel, M. (2018) Air pollution and autism in Denmark. *Environ Epidemiol*, **2**(4), pp. 1-13
68. Shrader-Frechette, K.S. (2012) *Environmental justice: Creating equity, reclaiming democracy*. New York, NY: Oxford University Press.
69. Soriano, J.B., Kendrick, P.J., Paulson, K.R., Gupta, V., Abrams, E.M. and Adedoyin, R.A. (2020) Prevalence and Attributable Health Burden of Chronic Respiratory Diseases, 1990-2017: A Systematic Analysis for the Global Burden of Disease Study 2017. *The Lancet Respiratory Medicine*, **8**, pp. 585-596.
70. Tessum, C.W., Apte, J.S., Goodkind, A.L., Muller, N.Z., Mullins, K.A. and Paolella, D.A, (2019) Inequity in consumption of goods and services adds to racial–ethnic disparities in air pollution exposure. *Proc Natl Acad Sci.* **116**(13), pp. 6001–6006.

71. Ucheje, O., Ogbuene, E.B. and Ofoezie, I.E. (2022) Trend Analysis of Vehicular Traffic Contribution to Air Pollution in Urban Cities: A Case Study of Port Harcourt, Nigeria. *Asian Journal of Environment & Ecology*, **17**(1), pp. 45-62
72. Ucheje, O.O. and Okolo, O.J. (2023) Contribution of Vehicular Emissions to Climate Change in Nigeria: A Closer Look. *International Journal of Environment and Pollution Research*, **11**(1), pp. 43-62
73. uMoya Nilu Consulting (2016) Fact-Finding Air Quality Monitoring Mission Report. Lagos.
74. UN (2019) News With a premature death every five seconds, air pollution is violation of human rights, says UN expert
75. Urhie, E., Adesola, A., Adedeji, A., Oluwatoyin, M., Osabohien, R. and Olabanji, E. (2020). Economic growth, air pollution and health outcomes in Nigeria: A moderated mediation model. *Cogent Social Sciences*. **6**, pp. 1719570.
76. Urhie, E., Odebiyi, J. and Popoola, R. (2017). Economic growth, air pollution standards enforcement and employment generation nexus in the Nigerian context. *International Journal of Innovative Research and Development*. **6**, pp. 19–27
77. USGCRP (2009). Global Climate Change Impacts in the United States. In: Karl TR, Melillo JM, Peterson TC, editors. *Climate Change Impacts by Sectors: Ecosystems*. New York, NY: United States Global Change Research Program. Cambridge University Press.
78. Usman, M., Zhiqiang, M., Muhammad, W. Z., Abdul, H. and Rana, U. A. (2019). Are Air Pollution, Economic and Non-Economic Factors Associated with Per Capita Health Expenditures? Evidence from Emerging Economies. *International Journal of Environmental Research and Public Health*. **16**, pp. 1967.
79. Volk, H.E., Hertz-Picciotto, I., Delwiche, L., Lurmann, F. and McConnell, R. (2011) Residential proximity to freeways and autism in the CHARGE study. *Environ Health Perspect*. **119**(6), pp. 873–877.
80. Volk, H.E., Lurmann, F., Penfold, B., Hertz-Picciotto, I. and McConnell, R. (2013) Traffic related air pollution, particulate matter, and autism. *JAMA Psychiat*. **70**(1) pp.71–77
81. Vom Saal, F.S., Woodruff, T.J., Soto, A.M., Skakkebaek, N.E., Gore, A.C. and Doan, L.L. (2012) Endocrine-disrupting chemicals and public health protection: a statement of principles from The Endocrine Society. *Endocrinology*, **153**(9), pp. 4097–4110.
82. Wambebe, N.M. and Xiaoli, D. (2021) Environmental Pollution and Health Effects - Addressing Pollution (Air, Water and Noise) Challenges in Africa and Possible Solutions Towards Attaining Sustainable Green Environment. *Int J Environ Sci Nat Res*. **27**(4), 1-8
83. WHO (2016) Air pollution levels rising in many of the world's poorest cities. In: WHO Global website, Media Centre [news release] (http://www.who.int/mediacentre/news/releases/2016/air-pollution-rising/en/) [Accessed 20th April 2023]

84. Whyte, M., Tamuno-Wari, N. and Kabari, S. (2020). Residents perception of the effects of soot pollution in Rivers State, Nigeria. *African Journal of Environmental Science and Technology*. **14**, pp. 422–30.
85. World Bank Group (2018) Pollution Management and Environmental Health, Annual Report. www.worldbank.org/pmeh [Accessed 20th April 2023]
86. World Health Organization (WHO) (2006) *WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide*: Global Update 2005.
87. World Health Organization (WHO) (2016) *Ambient (Outdoor) Air Pollution Database*. https://www.who.int/airpollution/data/cities-2016/en [Accessed 14th April 2023]
88. World Health Organization (WHO) (2018) *Global Ambient Air Quality Database*. https://www.who.int/airpollution/data/en [Accessed 29th March 2023]
89. Wu, X., Braun, D., Schwartz, J., Kioumourtzoglou, M.A. and Dominici, F. (2020) Evaluating the Impact of Long-Term Exposure to Fine Particulate Matter on Mortality among the Elderly. *Science Advances*, **6**(5692), pp. 1-13

90. Mbaoma, O. C., Ogunkeyede, A. O., Adebayo, A. A., Otolo, S. E., & Ikpinima, M. (2022). Geostatistical Analysis for Monitoring and Modelling Atmospheric Pollutants. Journal of Geography, Environment and Earth Science International, 26(6), 65–76. https://doi.org/10.9734/jgeesi/2022/v26i6631
91. Mishra, S. P., & Karmakar, T. (2024). Anthropocene Air Quality Impact on the Kolkata People. Advances in Research, 25(3), 50–68. https://doi.org/10.9734/air/2024/v25i31049
92. Kelly FJ, Fussell JC. Air pollution and public health: emerging hazards and improved understanding of risk. Environmental geochemistry and health. 2015 Aug;37:631-49.