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ANALYZING THE IMPACT OF AIR POLLUTION ON HUMAN HEALTH AND ENVIRONMENTAL SUSTAINABILITY IN KATSINA

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ABSTRACT

This study examines the impact of air pollution on human health and environmental sustainability in Katsina State, Nigeria. Air pollution poses a significant challenge globally, and Katsina is not exempt, with industrial activities, vehicular emissions and agricultural practices contributing to deteriorating air quality. The research focuses on major pollutants such as PM2.5, PM10, nitrogen oxides (NOx), sulfur dioxide (SO2) and carbon dioxide (CO2), analyzing their sources, trends and health implications. The findings reveal strong correlations between pollutant concentrations and increased respiratory and cardiovascular diseases, especially during seasonal spikes in pollution. Time series analysis demonstrates fluctuating pollution levels, exacerbating health outcomes like asthma, bronchitis and chronic obstructive pulmonary disease (COPD). The study also explores the broader environmental implications, showing that air pollution negatively affects ecosystem health, biodiversity and agricultural productivity, further threatening the region's environmental sustainability. These results highlight the urgency for stricter pollution control measures, adoption of cleaner technologies, and public awareness initiatives to mitigate air pollution's effects on both human health and the environment.

Keywords: Air Pollution; Human Health; Environment; Sustainability

1. INTRODUCTION

Air pollution has emerged as a critical global challenge, posing significant threats to both human health and environmental sustainability. Air pollution is one of the most significant challenges of our time. This issue is not only due to its contribution to climate change but also because of its severe impact on public and individual health, leading to increased rates of illness and death. Various pollutants play a major role in causing diseases in humans. Among these, particulate matter (PM), consisting of tiny particles of varying diameters, enters the respiratory system through inhalation, causing respiratory and cardiovascular ailments, disruptions in the reproductive and central nervous systems, and even cancer. In developing countries, the problem of air pollution is more serious due to overpopulation and uncontrolled urbanization, along with the development of industrialization (PM 2017). This leads to poor air quality, especially in countries with social disparities and a lack of information on sustainable management of the environment. The use of fuels such as wood or solid fuel for domestic needs, driven by low incomes, exposes people to poor-quality, polluted air at home. It is notable that three billion people around the world are using these sources of energy for their daily heating and cooking needs (Burden of Disease from Ambient and Household Air Pollution 2017). In developing countries, women seem to carry the highest risk for disease development due to their longer duration of exposure to indoor air pollution. Due to its fast industrial development and overpopulation, China is one of the Asian countries confronting serious air pollution (Y 2017). The lung cancer mortality observed in China is associated with fine particles (Y 2017). As stated already, long-term exposure is associated with deleterious effects on the cardiovascular system (PM 2017). However, it is interesting to note that cardiovascular diseases have mostly been observed in developed and high-income countries rather than in the developing low-income countries exposed highly to air pollution (MS 2017). Extreme air pollution is recorded in India, where the air quality reaches hazardous levels. New Delhi is one of the most polluted cities in India. Flights in and out of New Delhi International Airport are often canceled due to the reduced visibility associated with air pollution. Pollution is occurring in both urban and rural areas in India due to rapid industrialization, urbanization, and the rise in the use of motorcycle transportation. Nevertheless, biomass combustion for heating and cooking is a major source of household air pollution in India and Nepal. There is spatial heterogeneity in India, as areas with diverse climatological conditions and population and education levels generate different indoor air qualities, with higher PM2.5 levels observed in North Indian states (557–601 $\mu g/m^3$) compared to the Southern states (183–214 $\mu g/m^3$). The cold climate of the North Indian areas may be the main reason for this, as longer periods at home and more heating are necessary compared to the tropical climate of Southern India. Household air pollution in India is associated with major health effects, especially in women and young children, who stay indoors for longer periods. Chronic obstructive respiratory disease (CORD) and lung cancer are mostly observed in women, while acute lower respiratory disease is seen in young children under 5 years of age (Dherani M. 2008).

1.1 The Intersection of Air Pollution and Sustainable Development Goals: Policy and Global Perspectives

Elder and Zusman (2016) highlight the connections between air pollution and the Sustainable Development Goals (SDGs) in a Policy Brief for the Institute for Global Environmental Strategies. They establish a correlation between air pollution and 10 of the SDGs, identifying implicit connections within 14 of the 169 specific targets. Additionally, they emphasize that while air pollution may be indirectly linked to several other targets, some goals and targets do not explicitly address air quality concerns. Farmer (2018) explored how air pollution is connected to SDGs, particularly those addressing poverty, hunger, and gender equality. He stressed the importance of viewing the SDGs holistically within policy frameworks, urging government institutions to recognize how their contributions to one SDG can influence others. This interconnection is particularly significant for understanding the links between pollution and poverty reduction. The European Environment Agency’s 2017 report on Air Quality in Europe examined the relationship between air pollution and the SDGs. Citing UNICEF, the report acknowledged that European Union policies aimed at reducing air pollution and its effects directly or indirectly support the achievement of 12 of the 17 SDGs (UNICEF, 2016). The World Health Organization (WHO) also recognizes air pollution as a key issue within the framework of sustainable development. WHO describes air pollution as an indicator of sustainable progress, pointing out that policies to combat air pollution often yield additional health benefits, such as preventing injuries or promoting physical activity. WHO has taken responsibility for monitoring three air pollution-related indicators under the SDG framework (WHO, 2016).

1.2 The Critical Role of Environmental Health and the Atmosphere in Human Well-being Environmental health is closely linked to both human health and a balanced environment. It often hinges on the harmony between individuals and their surroundings, and disruptions to this balance can result in health issues (Botkin & Keller, 2007). Environmental health addresses external factors that contribute to disease, including the natural, social, cultural, and technological aspects of our world (Cunningham & Saigo, 2005). Disease, in this context, refers to an abnormal change in the body’s condition that interferes with physical or psychological functions (Cunningham & Saigo, 2005). According to Ahluwalia and Malhotra (2008), the environment encompasses air, water, and soil, with both natural and man-made elements. The natural environment includes everything that influences organisms throughout their lives, such as air, water, soil, forests, and wildlife. From a human perspective, environmental issues involve concerns related to science, nature, health, politics, and economics (Enger & Smith, 2000). However, environmental problems transcend political borders, and air pollution can range from local government concerns to international challenges (Enger & Smith, 2000). The environment is divided into four segments: the atmosphere, hydrosphere, lithosphere, and biosphere. The atmosphere, the layer of gases surrounding the Earth, is held in place by gravity and is crucial for sustaining life by protecting the planet from harmful ultraviolet rays and providing essential gases like oxygen and carbon dioxide (Kemp, 2004). Although ozone is a harmful pollutant in ambient air, it serves as a protective shield against ultraviolet radiation when found in the stratosphere (Cunningham et al., 2005). The atmosphere is composed of 79% nitrogen, 20% oxygen, and 1% carbon dioxide, water vapor, and trace gases. It consists of layers such as the troposphere, stratosphere, and ionosphere, each with varying densities (Enger & Smith, 2000). In addition to gases, the atmosphere contains non-gaseous particles like aerosols and particulate matter, which can result from natural processes like volcanic activity, fires, and biological processes (Kemp, 2004). These particles are often synonymous with air pollution, though they are naturally occurring. The atmosphere is vital for human survival, performing functions that allow life to thrive across the Earth’s surface (Kemp, 2004). Its ability to protect and support life highlights the deep connection between environmental health and the atmosphere, particularly in relation to air quality.

1.3 Urgency of Tackling Air Pollution Health Implications and Global Challenges

The introduction emphasizes the pressing need to address air pollution as a major environmental and public health issue. It underscores the importance of understanding its sources, components, and health effects to inform policy decisions. Air pollution is recognized as one of the most critical challenges today, not only due to its role in climate change but also because of its significant impact on public health, leading to higher rates of disease and mortality. Various pollutants contribute to human health problems, with particulate matter (PM) being one of the most harmful. PM consists of tiny particles that, when inhaled, enter the respiratory system, causing respiratory and cardiovascular diseases, reproductive and nervous system disorders, and even cancer. While ozone in the upper atmosphere protects against ultraviolet radiation, at ground level, high concentrations of ozone become harmful to the respiratory and cardiovascular systems. Other harmful pollutants include nitrogen oxide, sulfur dioxide, volatile organic compounds (VOCs), dioxins, and polycyclic aromatic hydrocarbons (PAHs), all of which pose health risks. Carbon monoxide, in elevated concentrations, can lead to immediate poisoning, while heavy metals like lead, once absorbed by the body, can cause acute poisoning or chronic health issues depending on exposure levels. The diseases resulting from these pollutants include chronic obstructive pulmonary disease (COPD), asthma, bronchiolitis, lung cancer, cardiovascular events, neurological disorders, and skin conditions. Moreover, climate change caused by environmental pollution affects the spread of infectious diseases and influences natural disasters, altering their geographical reach. Tackling this critical issue requires raising public awareness and adopting a multidisciplinary approach involving scientific experts. National and international organizations must take decisive action to confront this growing threat and implement sustainable solutions (Manisalidis, 2022).

1.4 Urban Air Pollution Impacts on Public Health and Environmental Challenges

Clean air is essential for the well-being of both humans and animals. However, with relentless urban development, air quality is continuously deteriorating. Urban areas are particularly affected, as they experience higher pollution levels than less-developed or natural environments due to dense populations and increased human activity (Ling et al., 2012). For instance, the urban conurbation of Klang Valley, characterized by heavy traffic and high development density, contributes significantly to declining air quality. In Malaysia, Kuala Lumpur saw an increase in unhealthy or hazardous air quality days, rising from 11 days in 2001 to 67 days in 2005 (Ling et al., 2010). The World Health Organization (WHO) recognizes urban air pollution as a critical public health issue, attributing over 2 million premature deaths annually to both outdoor and indoor air pollution (WHO, 2006). The impacts of air pollution are not limited to illness and death; they extend to lost productivity and missed educational and development opportunities (UN, 2001). Public awareness of the adverse effects of urban air pollution, such as respiratory illnesses and cardiovascular diseases, has grown, prompting a re-evaluation of current air quality standards (Coils & Micallef, 1997). The Clean Air Act of 1970 identified pollutants such as sulfur dioxide, carbon monoxide, particulate matter, volatile hydrocarbons, photochemical oxidants, and lead as major threats to human health (Cunningham et al., 2005). Among these, particle pollution and ground-level ozone are considered the most dangerous to human health. Epidemiological and laboratory studies have shown that ambient pollutants, including PM, O3, SO2, and NO2, contribute to respiratory issues like bronchitis, emphysema, and asthma (Ling et al., 2012). In Malaysia, the Ministry of Health (MoH) reported that respiratory diseases accounted for 10.36% of hospitalizations in 2011, while 19.48% of deaths in MoH hospitals during the same year were due to respiratory conditions (MoH, 2012). These statistics highlight the serious impact of air pollution on public health in the region. Nurul Ashikin et al. (2015) conducted a study on urban air quality and its effects on human health in Selangor, adhering to the Air Pollution Index (API) scale established by the Department of Environment (DOE). This approach was intended to enhance the understanding of air pollution data and its implications for human health. In a related study, Nurul Ashikin et al. (2014) examined the broader effects of air pollution on human health and well-being. Their research, which included both epidemiological and laboratory studies, highlighted that ambient air pollutants such as particulate matter (PM), ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) are linked to various respiratory conditions, including bronchitis, emphysema, and asthma.

Table 1. Sources of primary air pollutants

Pollutant	Sources
Carbon monoxide	Incomplete combustion of fossil fuels and tobacco smoke
Hydrocarbons	Partial combustion of fossil fuels
Particulates	- Tobacco combustion - Chemical emissions - Fossil fuel combustion - Agricultural practices - Construction activities - Industrial waste - Demolition of buildings
Sulphur dioxide	- Fossil fuel combustion - Ore smelting
Nitrogen compounds	- Combustion of fossil fuels

Source: Enger & Smith (2000)

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1.5 Atmosphere's Role in Sustaining Life and the Impact of Air Pollution

The atmosphere plays a crucial role in sustaining life by providing oxygen, regulating the Earth's energy through elements like the ozone layer and the greenhouse effect, and distributing heat and moisture across the planet. Additionally, it helps dispose of pollutants generated by both natural processes and human activities. However, when the atmosphere is unable to disperse or eliminate pollutants efficiently, the buildup of gases and aerosols leads to air pollution (Kemp, 2004). With the rapid expansion of the global population, pollution has become a widespread issue affecting everyone. Environmental pollution encompasses air, water, and soil contamination. According to Enger & Smith (2000), pollution occurs when human activities produce substances in large enough quantities to interfere with health and well-being. Factors contributing to pollution include population size and the development of technologies that introduce pollutants into the environment. In practical terms, pollution arises from the inefficiencies of human processes, such as raw material extraction, manufacturing, and energy production, which generate waste that cannot be reused (Wagner, 1994).

Air pollution refers to the physical or chemical changes caused by natural events or human activities that degrade air quality (Cunningham et al., 2005). The release of smoke and other pollutants into the air faster than they can be absorbed and dispersed creates unhealthy conditions (Enger & Smith, 2000). Historically, the presence of atmospheric pollutants, both natural and human-induced, has long been recognized. For instance, Leonardo da Vinci noted in 1550 the formation of a blue haze from materials released into the atmosphere by trees (Botkin & Keller, 2007). Air pollution is categorized into three types: natural pollutants, primary pollutants, and secondary pollutants. Natural pollutants arise from events like forest fires caused by lightning or the dispersal of pollen. This paper focuses on primary pollutants, which are materials released directly into the atmosphere in their unmodified form in sufficient quantities to pose health risks. These include carbon monoxide, hydrocarbons, particulates, sulfur dioxide, and nitrogen compounds (Enger & Smith, 2000). When these materials interact with energy sources, they form new secondary pollutants, such as ozone and other reactive chemicals in the atmosphere.

Hiba and Bijay (2023). Study the Impacts of Air Pollution on Human Health and Well-being: A Comprehensive Review presents an extensive examination of air pollution, its diverse sources, and its detrimental effects on both individual and community health

Addressing this problem requires a multidisciplinary approach that integrates scientific research, policy analysis, technological innovation, and community engagement. By examining the impact of air pollution on human health and environmental sustainability in a holistic manner, this research seeks to identify effective strategies and interventions to mitigate pollution levels, protect public health, and promote ecosystem resilience.

1.6 Objectives of the Study

This research aims to examine the impact of air pollution on both human health and environmental sustainability, providing a deeper understanding of the interconnectedness of air quality, public health, and ecosystem integrity. The study hope to achieve the following objectives:

- Determine major pollutants and analyze their sources, distribution patterns, and trends.
- Determine the relationship between air pollution exposure and respiratory, cardiovascular disease and other health outcomes.
- Determine the environmental impacts on ecosystems, including biodiversity loss and climate change.
- Determine socioeconomic disparities in exposure and assess economic costs associated with air pollution and Evaluate policies, technologies, and recommendations to mitigate air pollution's impacts.

2. RESEARCH METHOD

2.1 Study Area

The research was carried out in Katsina State, situated in northern Nigeria. Located about 160 miles east of Sokoto and 84 miles northwest of Kano, Katsina lies close to the Niger border. The area is a key agricultural center, cultivating crops like groundnuts, cotton, millet, and guinea corn, and is home to processing facilities for peanut oil and steel. The city's population is mainly Muslim, with the Fulani and Hausa ethnic groups being the predominant communities.

2.2 Data collection

The research used air quality index (AQI) data over time, which includes pollutants like PM2.5, PM10, NOx, and CO2, from local monitoring stations, environmental agencies, or satellite data. We also Obtain data on the prevalence of respiratory and cardiovascular diseases in Katsina from local hospitals or health departments. Use existing medical records or conduct interviews with healthcare professionals. and Gather ecological data, focusing on biodiversity, forest cover, and the state of ecosystems in the state over time.

2.3 Statistical Analysis

We Apply time series analysis to study the trends of pollutants (PM2.5, NOx, etc.) over several years in the state, then Analyze seasonal variations and patterns to understand pollution spikes and their sources we also Link time-series data on air pollution with health records from the selected hospital using correlation analysis to identify potential causal relationships.

3. RESULT AND DISCUSSION

This section provides a comprehensive analysis of air pollution trends and their impact on health outcomes in Katsina State. The primary pollutants under study include PM2.5, NOx, PM10, SO2, and CO2, while health variables include respiratory cases, cardiovascular cases, mortality related to cardio-respiratory illnesses, and COPD cases.

Time series analysis is conducted to track the trends of air pollutants over time, followed by correlation analysis to explore the relationship between air pollutants and health outcomes.

3.1 Timeseries Plot

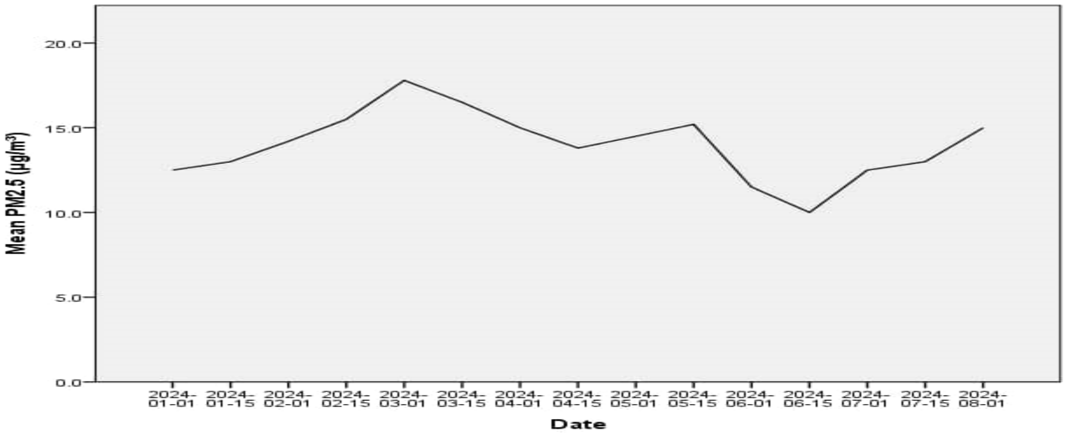

Fig. 1 The time series plot represents the trend of PM2.5 concentration levels in micrograms per cubic meter (µg/m³)

The time series plot represents the trend of PM2.5 concentration levels in micrograms per cubic meter (µg/m³) over a period from January to August 2024. From the graph, we observe that the PM2.5 levels exhibit fluctuations across the months, with peaks and troughs reflecting seasonal variations in air pollution. There is a noticeable increase in PM2.5 concentration during the early months, peaking around March 2024.

This peak might indicate higher pollution during the dry season or harmattan, which is common in regions like Katsina, where dust and particulate matter levels tend to rise.

After reaching its highest point in March, the PM2.5 levels gradually decrease, with a significant drop around June, possibly due to the onset of the rainy season. Rain typically helps settle airborne particles, reducing pollution. However, there is another small spike in July, indicating that pollution levels fluctuate even after a general decline.

The overall pattern shows that PM2.5 concentrations are sensitive to seasonal changes, and these fluctuations could be linked to health outcomes, such as increased respiratory issues during high pollution months. Further analysis would be needed to correlate this trend with hospital admissions or respiratory cases.

Time Series Model

Model Description			
			Model Type
Model ID	PM2.5 (µg/m³)	Model_1	Simple

The time series model used for PM2.5 concentrations is a simple model with no predictors. This model provides baseline statistics to understand the variability in PM2.5 concentrations across the months.

Table 2 Model Summary regarding its performance and limitations

Model Fit										
Fit Statistic	Mean	SE	Minimum	Maximum	Percentile					
					5	10	25	50	75	90	95
Stationary R-squared	-.011	.	-.011	-.011	-.011	-.011	-.011	-.011	-.011	-.011	-.011

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R-squared	.252	.	.252	.252	.252	.252	.252	.252	.252	.252	.252
RMSE	1.721	.	1.721	1.721	1.721	1.721	1.721	1.721	1.721	1.721	1.721
MAPE	10.264	.	10.264	10.264	10.264	10.264	10.264	10.264	10.264	10.264	10.264
MaxAPE	32.174	.	32.174	32.174	32.174	32.174	32.174	32.174	32.174	32.174	32.174
MAE	1.393	.	1.393	1.393	1.393	1.393	1.393	1.393	1.393	1.393	1.393
MaxAE	3.700	.	3.700	3.700	3.700	3.700	3.700	3.700	3.700	3.700	3.700
Normalized BIC	1.266	.	1.266	1.266	1.266	1.266	1.266	1.266	1.266	1.266	1.266

The model's summary statistics reveal several key insights regarding its performance and limitations. The negative stationary R-squared value (-.011) indicates that the model fails to capture the underlying patterns in the data, such as trends or seasonality, suggesting that a more sophisticated approach may be needed. This result suggests the presence of temporal dynamics or non-stationarity in the dataset that the current model overlooks. Additionally, the R-squared value of .252 implies that the model explains only 25.2% of the variance in PM2.5 levels, which is relatively low. This further reinforces the idea that the model might benefit from including additional factors, such as seasonal components or other external variables, to improve its explanatory power.

The error metrics offer additional insights into the model's predictive performance. The RMSE of 1.721 suggests that, on average, the model's predictions deviate from actual data points by approximately 1.72 units, reflecting a moderate level of accuracy but also indicating room for improvement. The MAPE, at 10.264%, shows that the model's predictions are off by about 10.26% on average, which may be acceptable in some contexts but highlights that the model could be improved for greater precision. The maximum absolute error (MaxAE) of 3.700 demonstrates that there are instances where the model significantly underestimates or overestimates certain data points. Lastly, the normalized BIC value of 1.266 suggests that while the model is relatively simple, it likely does not capture all the dynamics of the dataset, reinforcing the need for a more complex model that can address the limitations and better fit the observed data.

Table 3: Model Statistics of PM2.5 concentrations (in µg/m³)

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
PM2.5 (µg/m³)-Model_1	0	-.011	.	0	.	0

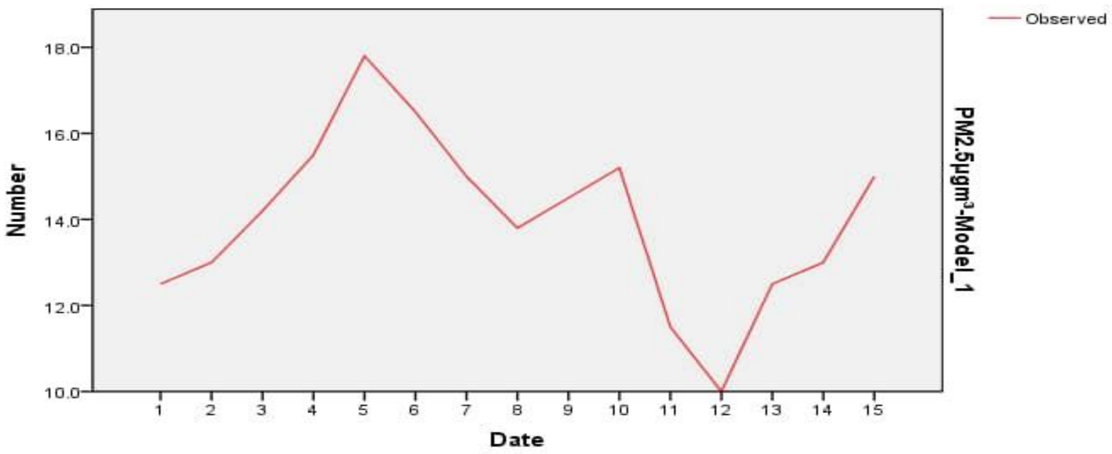

Fig. 2 The observed levels of PM2.5 concentrations (in µg/m³) over a period of 15 time points

The graph illustrates the observed levels of PM2.5 concentrations (in µg/m³) over a period of 15 time points, capturing the fluctuations in air quality that are critical to understanding its health impact. The line plot shows a sharp rise in PM2.5 levels from around 12 µg/m³ at the start to a peak of 18 µg/m³ around the 5th time point. This is followed by a gradual decline, with the lowest point observed near 11 µg/m³ at the 12th time point, after which there is a slight increase toward the end. These fluctuations suggest varying levels of air pollution over time, which, according to the research,

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strongly correlate with respiratory and cardiovascular health outcomes. Peaks in PM2.5 concentration indicate periods where health risks are likely higher, as PM2.5 is associated with increased mortality rates from cardio-respiratory illnesses.

These fluctuations underscore the importance of continuous air quality monitoring and targeted intervention during periods of high pollution. The significant rise between the 3rd and 5th time points could indicate a spike in hospitalizations or mortality due to respiratory illnesses, emphasizing the need for timely measures to mitigate pollution levels. Meanwhile, the dips in the graph might correspond to relatively safer periods, presenting opportunities to evaluate the effectiveness of air quality regulations. Overall, the data reflected in the graph can be used for further correlation analysis to explore the temporal relationship between these PM2.5 spikes and adverse health outcomes, reinforcing the urgency of reducing pollution to improve public health.

Table 4. The correlation analysis between air pollutants and various health outcomes

		PM2.5 (µg/m^3)	**NOx (ppb)**	**PM10 (µg/m^3)**	**SO2 (ppb)**	**CO2 (ppm)**	**Respiratory Cases**	**Cardiovascular Cases**	**Mortality (Cardio/Respiratory)**	**COPD Cases**
PM2.5 (µg/m^3)	Pearson Correlation	1	.917**	.978**	.905**	.905**	.866**	.927**	.959**	.923**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000
	N	15	15	15	15	15	15	15	15	15
NOx (ppb)	Pearson Correlation	.917**	1	.938**	.947**	.956**	.874**	.903**	.895**	.852**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000
	N	15	15	15	15	15	15	15	15	15
PM10 (µg/m^3)	Pearson Correlation	.978**	.938**	1	.897**	.896**	.909**	.947**	.970**	.940**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000
	N	15	15	15	15	15	15	15	15	15
SO2 (ppb)	Pearson Correlation	.905**	.947**	.897**	1	.911**	.819**	.924**	.907**	.883**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000
	N	15	15	15	15	15	15	15	15	15
CO2 (ppm)	Pearson Correlation	.905**	.956**	.896**	.911**	1	.840**	.864**	.852**	.776**

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	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.001
	N	15	15	15	15	15	15	15	15	15
Respiratory Cases	Pearson Correlation	.866**	.874**	.909**	.819**	.840**	1	.916**	.882**	.868**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000
	N	15	15	15	15	15	15	15	15	15
Cardiovascular Cases	Pearson Correlation	.927**	.903**	.947**	.924**	.864**	.916**	1	.980**	.959**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000
	N	15	15	15	15	15	15	15	15	15
Mortality (Cardio/Respiratory)	Pearson Correlation	.959**	.895**	.970**	.907**	.852**	.882**	.980**	1	.981**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000
	N	15	15	15	15	15	15	15	15	15
COPD Cases	Pearson Correlation	.923**	.852**	.940**	.883**	.776**	.868**	.959**	.981**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.001	.000	.000	.000	
	N	15	15	15	15	15	15	15	15	15

Correlation is significant at the 0.01 level (2-tailed).

The correlation analysis highlights significant relationships between air pollutants and various health outcomes, illustrating the profound impact of environmental factors on public health. PM2.5 (fine particulate matter) stands out with its strong positive correlations with several health conditions. Notably, PM2.5 has a correlation of .866 with respiratory cases and .927 with cardiovascular cases, indicating that higher levels of this pollutant are associated with an increase in these health problems. The strongest correlation is with mortality related to cardio-respiratory illnesses (.959), suggesting that PM2.5 concentrations are closely tied to death rates. This makes PM2.5 a critical variable in public health discourse, as reducing its levels could significantly lower mortality rates and reduce the incidence of respiratory and cardiovascular diseases. The findings stress the urgency for targeted interventions that address PM2.5 emissions, which are typically linked to industrial activities, vehicle emissions, and other urban pollution sources.

NOx (nitrogen oxides), another pollutant analyzed, shows similarly high correlations with health outcomes. The correlation between NOx and PM2.5 is .917, demonstrating that these pollutants are often found together, likely originating from similar sources such as vehicle emissions and industrial processes. NOx has strong correlations with respiratory cases (.874) and mortality related to cardio-respiratory illnesses (.895), indicating that this pollutant is also a significant contributor to public health issues. PM10 (larger particulate matter) follows a similar pattern, with particularly high correlations with mortality (.970) and COPD cases (.940), reinforcing the conclusion that particulate matter, regardless of size, has serious health implications. The fact that PM10 and PM2.5 are both linked with heightened risks of mortality and chronic health conditions underscores the importance of reducing particulate pollution to mitigate long-term health effects.

Other pollutants such as SO2 (sulfur dioxide) and CO2 (carbon dioxide) also display meaningful correlations with health outcomes. SO2, primarily produced by fossil fuel combustion, has a strong correlation with respiratory cases (.819) and cardiovascular cases (.924), suggesting that its presence in the atmosphere significantly exacerbates respiratory and cardiovascular diseases. Although CO2 itself shows slightly weaker correlations with health outcomes, such as respiratory cases (.840) and cardiovascular cases (.864), it still poses a health risk, particularly because it is often emitted alongside more harmful pollutants. These findings emphasize the interconnectedness of environmental sustainability and human health, showing that reducing emissions not only benefits the ecosystem but also significantly alleviates the burden of disease. Implementing stricter air quality regulations and pollution controls in Katsina could result in considerable improvements in public health, particularly by reducing the prevalence of cardio-respiratory diseases and associated mortality.

4. DISCUSSION OF THE FINDINGS

The findings from the analysis reveal a clear and concerning link between air pollutant concentrations, particularly PM2.5, and adverse health outcomes in Katsina. The Pearson correlation analysis demonstrates strong and statistically significant relationships between PM2.5 and a variety of health issues, including respiratory and cardiovascular cases. For instance, the correlation between PM2.5 and respiratory cases is exceptionally high (.866), while the correlation with cardiovascular cases is even stronger (.927). Most notably, PM2.5 is strongly correlated with mortality related to cardio-respiratory illnesses, with a near-perfect correlation of .959. This indicates that periods of higher PM2.5 concentrations are closely associated with increases in mortality, suggesting that efforts to reduce PM2.5 levels could have a profound impact on public health. These findings are consistent with global research that has identified PM2.5 as a leading cause of pollution-related diseases, underscoring the need for strict regulatory measures to control particulate matter emissions in urban environments like Katsina.

In addition to PM2.5, the study highlights the significant role of other pollutants, such as nitrogen oxides (NOx), PM10, sulfur dioxide (SO2), and carbon dioxide (CO2), in contributing to adverse health outcomes. NOx, which is highly correlated with PM2.5 (.917), shows strong correlations with respiratory and cardiovascular cases, further emphasizing the impact of vehicle emissions and industrial pollutants on public health. PM10, another key particulate matter pollutant, is most strongly correlated with mortality related to cardio-respiratory illnesses (.970), reinforcing the findings that particulate matter, regardless of size, is a major driver of respiratory and cardiovascular diseases. SO2 also emerges as a significant pollutant, with strong correlations to respiratory cases (.819) and cardiovascular cases (.924). These findings suggest that efforts to reduce emissions of SO2, commonly a byproduct of fossil fuel combustion, could help alleviate the burden of respiratory and cardiovascular illnesses. While CO2 has a relatively lower correlation with health outcomes, its significance lies in its association with other harmful pollutants, indicating that measures to curb CO2 emissions could indirectly improve air quality and health outcomes.

Overall, the time series analysis and correlation matrix provide compelling evidence that air pollution, particularly PM2.5, NOx, PM10, and SO2, is closely linked to negative health outcomes in Katsina. The significant correlations between these pollutants and health variables underscore the need for immediate policy interventions to reduce pollution levels. The graph showing PM2.5 fluctuations over time further emphasizes the urgency of addressing pollution peaks, as these are likely periods of heightened health risks. Reducing air pollution in Katsina is not just an environmental imperative but also a critical public health concern. Implementing stricter air quality standards, promoting cleaner technologies, and enhancing public awareness about the health risks associated with air pollution could significantly lower the rates of respiratory and cardiovascular diseases, improving the overall well-being of the population.

4. Conclusion

The research underscores the critical need to address air pollution as a growing public health and environmental concern in Katsina State. The correlation between elevated levels of air pollutants and adverse health outcomes, such as respiratory and cardiovascular diseases, is evident and calls for immediate action. Industrial activities, vehicular emissions, and agricultural practices contribute significantly to pollution, exacerbating health risks and environmental degradation. Additionally, the study reveals that air pollution's impact extends beyond health, threatening the region's environmental sustainability by reducing air quality, affecting agricultural output, and disrupting ecosystems. To mitigate these challenges, there is an urgent need for comprehensive pollution control strategies, including stricter air quality regulations, the promotion of cleaner technologies, and public education on the health risks associated with poor air quality. Collaborative efforts between local communities, government bodies, and international organizations will be essential in reducing air pollution and protecting both human health and environmental integrity in Katsina State.

5. RECOMMENDATION

The following recommendation are made for the stakeholders in order to overcome the situation

- Implement and enforce stricter air quality standards and regulations to control emissions from industrial sources, vehicles, and agricultural activities. Regular monitoring and compliance checks should be conducted to ensure adherence to these standards.
- Encourage the adoption of cleaner technologies and practices in industrial processes and transportation. This includes promoting the use of alternative fuels, implementing energy-efficient technologies, and investing in renewable energy sources.
- Conduct awareness campaigns to educate the public about the health risks associated with air pollution and the importance of reducing personal and community-level pollution sources. Engaging local communities in environmental conservation efforts can also help mitigate pollution.
- Develop and implement urban planning strategies in the state that reduce pollution, such as creating green spaces, improving waste management systems, and enhancing public transportation infrastructure to reduce vehicular emissions.
- Increase investment in healthcare facilities of state own hospitals and programs to address the health impacts of air pollution. This includes providing resources for early diagnosis, treatment, and management of pollution-related diseases.
- Advocate for and support the implementation of environmental policies and agreements, such as those outlined in international protocols and agreements, to address global and local pollution challenges effectively.

6. RESEARCH CONTRIBUTION

This research contributes to the understanding of air pollution's impact on human health and environmental sustainability in Katsina by providing a detailed analysis of pollutant sources, health effects, and environmental consequences. The study offers valuable insights into the specific challenges faced by the state and highlights the need for targeted interventions. It serves as a critical resource for policymakers, public health officials and environmental advocates working to improve air quality and promote sustainable development in Katsina state and Northern Nigeria.

7. REFERENCES

[1] Ahluwalia, V. K., & Malhotra, S. (2008). Environmental Science. Delhi, India: Ane Books India
[2] American Lung Association (2013). American Lung Association State of the Air 2013 - Health
[3] Effects of Ozone and Particle Pollution. Retrieved from http://www.stateoftheair.org/2013/health-risks/
[4] Botkin, D. B., & Keller, E. A. (2007). Environmental science: Earth as a living planet. Hoboken, NJ: Wiley.
[5] Brebbia, C.A., Longhurst, J.W.S., Marco, E. & Booth, C. (eds), Sustainable Development and Planning IX. WIT Transactions on Ecology and the Environment, vol. 226, WIT Press: Southampton and Boston, 2017.
[6] Coils , J. J., & Micallef , A. (1997). Towards Better Human Exposure Estimates for Setting of Air Quality Standards. Atmospheric Environment, 31(24), 4253.
[7] Cunningham, B., Cunningham, M. A., & Saigo, B. W. (2005). Environmental Science: A Global Concern (8th ed.). Boston: McGraw Hill.
[8] Cunningham. (2005). "Notes on education and research around architecture".The Journal of Architecture 415-441.
[9] Dherani M, Pope D. 2008. "ndoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis."
[10] Elder, M. & Zusman, E., Strengthening the Linkages Between Air Pollution and the Sustainable Development Goals. Policy Brief 35. Institute for Global Environmental Strategies, 2016, Online.https://pub.iges.or.jp/system/files/publication_documents/pub/policy/5528/PB_35_0707_2.pdf. Accessed on: 21 May 2018.
[11] Enger, E. D., & Smith, B. F. (2000). Environmental science: A study of interrelationships (7th ed.). Boston, Mass: McGraw-Hill.
[12] European Environment Agency, Air quality in Europe—2017 report, EEA Report No 13/2017, Copenhagen, 2017.
[13] Farmer, A., Tackling pollution is essential for meeting SDG poverty objectives. Perspectives 27, UN Environment, Online. https://ieep.eu/publications/industrialpollution-and-chemicals/tackling-pollution-is-essential-for-meeting-sdg-povertyobjectives. Accessed on: 21 May 2018
[14] Hiba, G., Bijay, K. D. (2023). The Impacts of Air Pollution on Human Health and Well-being: A
[15] Comprehensive Review, *Journal of Environmental Impact and Management Policy* · October 2023

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[16] Kemp, D. D. (2004). Exploring environmental issues: An integrated approach. London, United Kingdom: Routledge.
[17] Ling, O. L., & Ting, K. H. (2010). Air Quality and Human Health in Urban Settlement : Case Study of Kuala Lumpur City.
[18] Ling, O.H.L, Shaharuddin, A., Kadaruddin, A., Yaakub, M. J., & Ting, K. H. (2012). Urban Air Environmental Health Indicators for Kuala Lumpur City. Sains Malaysia, 41(2), 179-191.
[19] Ling, O.H.L. (2012). Air Quality and Human Health in Urban Settlement: Case Study of Kuala Lumpur City. PhD Thesis: Universiti Kebangsaan Malaysia.
[20] Manisalidis, Ioanis. (2022). “Environmental and health impacts of air pollution-A review.” Greece.
[21] Ministry of Health Malaysia (MoH) (2012). Health Facts 2012 (MOH/S/RAN/31.12 TR).
[22] Putrajaya, Malaysia: Health Informatics Centre.
[23] MS, Burroughs Peña. 2017. A. Environmental exposures and cardiovascular disease: a challenge for health and development in low- and middle-income countries. Cardiol Clin.
[24] Nurul Ashikin, B. M., Oliver, L. H., Leh, and Dasimah ,O. (2014). Human Health and Wellbeing:
[25] Human Health Effect of Air Pollution,*Procedia - Social and Behavioral Sciences*, 153, 221-229,
[26] Nurul Ashikin, B. M., Oliver, L. H., Leh, and Dasimah,O. 2015). Urban Air Quality and Human
[27] Health Effects in Selangor, Malaysia, *Procedia - Social and Behavioral Sciences, 170,* 282-291,
[28] PM, Manucci. 2017. “Health effects of ambient air pollution in developing countries.” Int J Environ Res Public Health.
[29] UNICEF, Clear Air for Children. The Impact of Air Pollution on Children, United Nations Children’s Fund: New York, 2016.
[30] WHO, World Health Statistics 2016: Monitoring Health for the SDGs, World Health Organization: Geneva, 2016.
[31] World Health Organization. (2006). WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: Global assessment 2005: summary of risk assessment. Geneva, Switzerland: World Health Organization.
[32] Y, Guo. 2017. The burden of lung cancer mortality attributable to fine particles in China. China: Total Environ Sci 2016. “Paris Climate Change Agreement,.”
[33] 2017. “Burden of Disease from Ambient and Household Air Pollution.”2019. “Copenhagen Climate Change Conference (UNFCCC).