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Review Article

Effects of Ozone, Particulate Matter10 and Oxides of Nitrogen on Respiratory Health (COPD and asthma) in Nigeria: A Systematic Review

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Abstract

Background: Nigeria has the largest population of any African country, with 190 million people, and has the largest economy in Africa. Nigeria has become one of the most polluted countries in the globe as a result of recent industrial and population development, coupled with lax regulatory enforcement and a rapid rise in the urban population. This has led to increased emissions of particulate matter, nitrogen oxides, and other pollutants, with consequent harm to the respiratory health of many. This paper is a systematic review of empirical research on air pollution, specifically from ozone, particulate matter, and nitrogen oxides, and their effect on respiratory health in Nigeria.

Methods: Through systematic searching, published research on the effects of air pollution caused by ozone, particulate matter, and nitrogen oxide on respiratory health in Nigeria were obtained from the Discover, PubMed, Google Scholar, and Web of Science databases.

Results: In total, 3,287 publications were returned. The outcome was refined to include only studies with keywords, abstracts, and titles in the last 10 years 27 publications returned. The studies were further appraised for relevance, quality, and studies conducted in Nigeria only, and 11 studies were produced.

Conclusion: The effect of ozone, PM, and nitrogen oxides on respiratory health such as COPD and asthma in Nigeria has risen in the past few years but no study on the effects of O3, PM10, and NOx on Respiratory Health (COPD and asthma) in Nigeria. This review recommends the need for national, state, and local epidemiological data and vital strategies to mitigate the health burden in Nigeria. Global research networks of nations with high pollution levels and scarce resources are critical for generating public support for reducing air pollution and engaging in green technology.

Keywords: Air Pollution; Asthma; Nigeria; COPD; O3; PM; NOX

Introduction

Air pollution is one of this generation's greatest scourges, not only for its impact on climate change but also on respiratory health due to increased sickness and mortality. Several pollutants play a major role in human disease. Particulate Matter (PM) penetrates the respiratory system via breathing and triggers respiratory and cardiovascular disease, nervous system and reproductive problems, and cancer [1]. Ground level ozone is toxic, damaging the cardio vascular and respiratory systems. Nitrogen oxide is also classified as a hazardous air pollutant. The illnesses caused by the chemicals mostly affect the respiratory system, including Chronic Obstructive Pulmonary Disease (COPD), asthma, bronchiolitis, and lung cancer. The best way to solve this issue is via increased awareness and a multidisciplinary approach by scientific professionals; national and international bodies to confront and provide solutions to air pollution. Air quality in developing nations such as Nigeria is unsafe and

has repeatedly been observed to be higher than the WHO standard, with 9 out of 10 breathing polluted air in developing countries such as Nigeria (WHO, 2018). Despite declines in air pollution in most countries, poor outdoor air quality remains a major health threat in Nigeria [2] (WHO, 2018; Global Burden of Disease, 2019; Health Effects Institute, 2020). Because of this, this study is dedicated to a systematic review of such problems in Nigeria.

Particulate Matter (PM): Particulate matter is composed of microscopic liquid or solid particles that may be inhaled and have a detrimental effect on health [3]. Particulate matter is produced in the atmosphere resulting from chemical interactions between various contaminants. PM is composed of organic compounds (benzene, dioxins, polycyclic aromatic hydrocarbons, and 1-3 butadiene) and inorganic compounds (chlorides, carbon, nitrates, metals, and sulphates) [3]. Particle penetration is highly dependent on their size [4]. After inhalation, particles 10μm in diameter (PM_{10}) may enter the lungs and potentially reach the bloodstream. $PM_{2.5}$ particles, owing to their microscopic size, are associated with more severe health consequences than PM_{10}. Numerous studies have shown a link between particulate matter and unfavorable health consequences, focusing on either acute (short-term) or chronic (long-term) PM exposure. Numerous epidemiological studies on the health consequences of PM have been conducted. Long-term exposure to PM is associated with cardiovascular illness and neonatal mortality. Respiratory illnesses and immune system dysfunctions are widespread in Nigeria [5]. Those with asthma, diabetes, pneumonia and cardiovascular and respiratory illnesses are more susceptible and sensitive to the effects of PM.

Ozone: Ozone (O_3) is produced is formed by a chemical process between nitrogen oxides and volatile organic compounds (VOCs) emitted by natural sources and/or anthropogenic activities. It occurs in the stratosphere, but it may also occur due to photochemical smog chain reactions in the troposphere [6]. Ozone levels above cities are modest compared to the increasing levels in metropolitan regions in Nigeria. Ozone is typically absorbed via inhalation and also interferes with the function and integrity of the skin barrier. Ozone's toxic effects have been documented in metropolitan areas worldwide, producing morphologic, biochemical, immunological, and functional problems [7-10].

Nitrogen Oxide: Nitrogen oxide is a contaminant associated with traffic as it is produced by automobile engines [11,12]. It is a respiratory irritant that penetrates deeply into the lung, causing respiratory problems such as coughing, dyspnoea, wheezing, bronchospasm, and pulmonary edema at high concentrations. Concentrations over 0.2ppm lead to detrimental effects in humans. In comparison, concentrations greater than 2ppm appear to impact T-lymphocytes, especially CD8+ and NK cells, responsible for immunological response [12]. Lengthy exposure to high levels of nitrogen dioxide has been implicated in the development of chronic lung illness as well as irritation of the eyes, throat, and nose [13]. This study conducted a laborious review of existing studies that have reported on the effect of Ozone, Particulate Matter10, and Oxides of Nitrogen on Respiratory Health (COPD and asthma) in Nigeria with the aim of recognising and generating an understanding of the effect of these pollutants of COPD and asthma.

Methodology

Systematic reviews

A comprehensive and exhaustive overview of recent literature collected from multiple databases and relating to a research topic is given in systematic reviews. The papers were retrieved from Scopus, PubMed, Discover, Google Scholar, and Web of Science databases.

Eligibility

Studies examining respiratory impacts (NO_x, PM, and O_3) on humans were considered. All the studies considered looked at the effect of air pollution on respiratory health, which a special interest in particulate matter, nitrogen oxides, and ozone in Nigeria. Duplicates of studies were eliminated, and abstracts were independently reviewed, with any disputes addressed by bringing in a second investigator. The final studies were chosen by inclusion criteria that have tried to regulate the main confounding factors (such as meteorological trends and season and smoking and prevailing medical issues for cohorts) and had recorded respiratory health outcomes. The research did not put any limitations on research design; however, only publications in English were included.

Search Strategy

Search strategy and selection criteria: A systematic search of the literature on the effect of air pollutants (O_3, PM_{10} and NO_x) on COPD and asthma was conducted. The following databases were searched: PubMed, EMBASE, and Discover. Peer-reviewed journals and panel papers from organizations on air pollution associated with O_3, PM_{10}, and NO_x were reviewed.

Inclusion criteria:

To achieve the aim of this systematic review, the following criteria were used in the selection of the relevant publications and reports.

a) There were no restrictions on publication dates and online database search to include studies conducted on same air pollutants.

b) The study reported any effect of O_3, PM_{10} and NO_x associated with COPD and asthma conditions in Nigeria.

c) The study adopted a quantitative research method.

The search on Discover, PubMed, Web of Science, EMBASE, and Biomedical databases, on all peer-reviewed time series and published panel papers, produced a total of 3,287 articles. The outcome was refined to include only studies with keywords, abstracts, and titles. Subsequently, abstracts and titles of studies included were reviewed for relevance so that studies without the effect of O_3, PM_{10}, and NO_x were excluded, and 22 studies were found. Fewer journals on either O3, PM10, and NOx were found when the search was re-

stricted to studies conducted in Nigeria. A manual and grey search method was used to note studies that might not have been noticed and ensure that the search was exhaustive on all studies conducted in Nigeria. This approach yielded 27 studies and 27 studies were further appraised for relevance and quality. The appraisal entailed reading the 27 articles, and this was carried out using the Cochrane Library's recommended principles (transparency, methodological rigor, and reproducibility) (Cochrane, 2007). Based on the recommended principles, the studies were examined for reliability and validity, and the areas of appraisal included but were not limited to the sampling method, data collection, sample size, study population, and statistical process used in the analysis and its significance. At the end of the appraisal and assessment, 11 studies were included in this systematic review based on the recommended principles. Figure 1 below is a PRISMA diagram of the systematic review procedure.

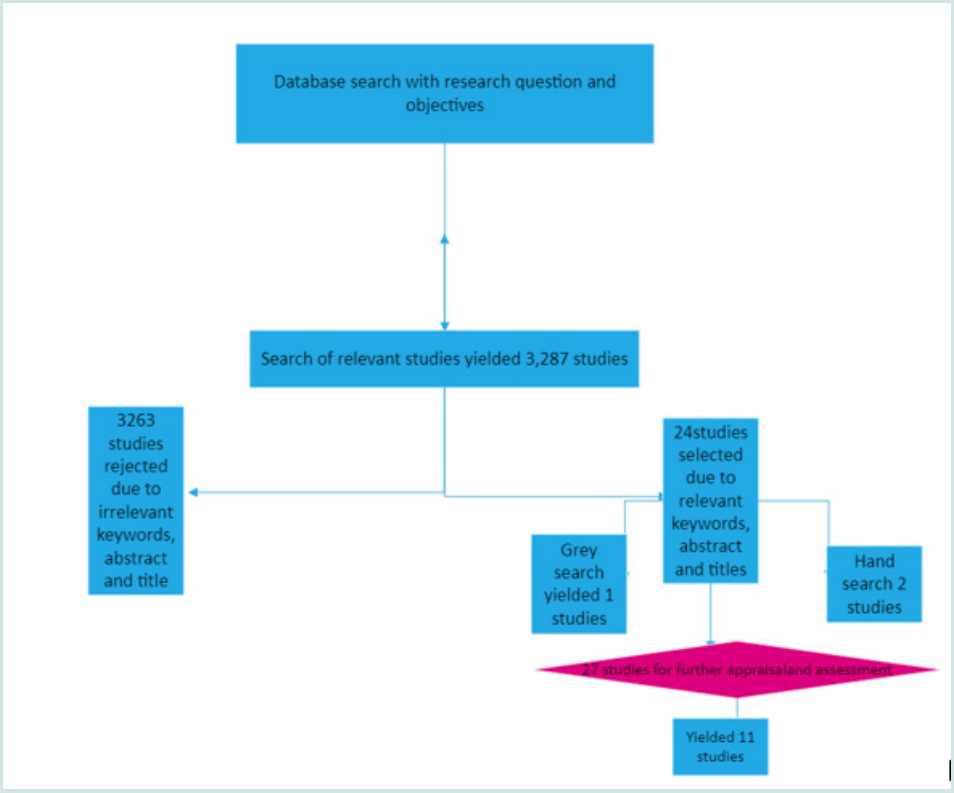

Figure 1: PRISMA diagram of the systematic review process.

Data Extraction

The data were extracted and stored in a database. Study design and population demographics, research time, type of respiratory events, pollutant type, area, confounders addressed, city, exposure classification technique, analytical methodologies, and effect estimations by pollutant, outcome, and related lag time were all extracted from each study. Ten percent of the extracted research data were first examined and found no discrepancies. The remaining data were then examined and validated from the retrieved data. To demonstrate the effects of NO_x, PM, and O_3 on respiratory health, any information regarding the same was analyzed. A narrative method was adopted in synthesizing the findings from the included studies. This method was ideal for considering the data from the selected studies to review the effects of O_3, NO_x, and PM_{10} on COPD and asthma patients in Nigeria. The researcher carried out the data extraction independently, although this was cross-checked by the supervisory team to ensure that all the data extracted were relevant. An agreement was reached on the final data extracted and used in the synthesis. The information extracted included: population description, location, study timeframe, year of publication, sample, results, study design, setting, and number and type of participants. As the systematic review aimed at identifying the effect of O_3, PM_{10}, and NO_x on COPD and asthma, and considering the data obtained, a vote count approach was chosen as the most appropriate for synthesizing the data in this systematic study.

The vote count is a quantitative method consisting of sorting, counting, and identifying a particular variable(s) in all the included studies. Vote counting uses the frequencies or percentages of these variables in the data set to make valuable conclusions by considering the outcome and strength of the statistical test for significance (Light and Smith, 1971; Heyvaert, Hannes, and Onghena, 2016). As presented in Table 1, the variables used for the vote counting of the extracted data were the location of the study, the ethnicity of the study population, socioeconomic status of the study populations of

the study population, age of study, and methods used in the studies. Moreover, the vote count method can either count the number of studies with negative or positive direction with or without statistical significance (Bushman, 1994). Although with this approach, there is a number of disadvantages vote-counting in one direction does not provide the quantity of difference between the groups (effect size) or vote counting gives the same weight to different studies, therefore, the ambiguity around the statistical significance and underpowered assessments in clinically significant but statistically not significant effects would be counted as "no effect.

Table 1:

Variables	Population	Pollutants	Vote counts	Outcome
Location	Northern Nigeria	PM_{10}, Traffic-related air pollution	3	A significant relationship between pollutants and respiratory symptoms (P=0.005) (3)
	Eastern Nigeria	PM	2	Significant association with difficulty in breathing in male and female with higher effect on female
	Western Nigeria	PM_{10}, NO_2, and photochemical oxidant	8	Six of the studies conducted in developing countries were significantly associated with FEV1, and 5 observed a strong positive association with increased symptoms (8)
	Southern Nigeria	PM (soot) and NO_X	6	Studies conducted in northern Nigeria 2 were significantly associated with decreased lung function(P<0.005). Three found an association with increased respiratory symptoms and 3 showed higher odds ratio for decreased FEV1 and worsened symptoms
Socioeconomic Status	Poverty, Education and Occupation	PM_{10}, NO_X	3	Weak evidence was found for high association with poverty, and significant association (p<0.005) with education was observed (3)
Sex	Men and Women	PM_{10}, O_3, NO_X	31	A strong association was observed(p<0.005) with women (5), no association with women (1); association with men and women (4) stronger association with men (3)
Age	Children and adult	PM_{10}, O_3, NO_X	24	There was a strong significant association on the asthmatic symptom in children (2) and stronger association on decreased FEV1(p<0.005) for adults (4).
Methods	Hospital record, questionnaire, and spirometry	PM_{10}, O_3, NO_X	49	Five studies used questionnaires and spirometry, 2 only questionnaires, 5 only hospital record and 6 used hospital record, questionnaire, and spirometry (10).

In order to overcome these disadvantages, more explicit analytical approaches of vote count reporting were explored:

a) The number of studies showing direction and strength of association.

b) Including the age, sex socioeconomic status and sensitive population

c) The number of studies showing statistically significant effects.

This allows for assessing the likely association, and effects in all studies included. By utilizing these more explicit approaches we include relevant information from all the reviewed studies. As such, vote count method provided a useful platform for this systematic review and this method has been widely used in medicine (Cook et al., 1992; Hölzel et al., 2011) and public health (Gerrard et al., 1996; Flodgren et al., 2011).

Risk of Bias

Due to the lack of a standardized documented framework to assess bias in environmental epidemiological data, the risk of bias was assessed concerning the following biases determined a priori: selection bias, detection bias, exposure categorization bias, and the confounding variables addressed. Some exposure categorization bias was anticipated in most included studies as many epidemiological data often employ fixed-site surveillance as a proxy for personal exposure. This review assigned a medium risk of exposure bias to studies that determined exposure status using more than three fixed-site monitors but a high risk to those that utilized three or less. Low risk was assigned to studies that utilized atmospheric modelling or human exposure assessments. Studies that lacked clinical validation or used ICD coding to quantify health outcomes were considered high risk of detection bias. In contrast, those lacking representative research populations were considered to be at high risk of selection bias. Lastly, publications that did not account for at least three major confounding variables, seasonality, weather, influenza, long-term trends, and demographic and lifestyle factors, were given a high risk of bias.

Results

Different studies on air pollution that affect respiratory health in different ages and countries have been searched by the systematic review. Many studies assessed O_3, NO_x, and PM_{10} on COPD and

asthma symptoms in developed countries and China but none have reviewed these three pollutants O_3, NO_x, and PM_{10} effect on COPD and asthma in Nigeria. This research aimed to research the effects of ozone, particulate matter, and nitrogen oxides on respiratory health in Nigeria. The Discover, PubMed, Google Scholar, and Web of Science databases were utilized to retrieve relevant papers [15]. The search queries included keywords identified in current published systematic reviews (Orellano et al., 2017). The consolidated results of the search queries were then filtered by introducing exclusion and limitation components.

General findings on effects of O_3, PM_{10}, and NO_X on Respiratory Health in Nigeria

Ozone (O_3)

Through oxidative damage and inflammation, ozone is known to induce a bronchial inflammatory response and airway hyper-responsiveness, as seen in most studies reviewed. Even though air pollutants like PM_{10} and NO_x have shown declining trends in average concentrations in recent years in Nigeria and other parts of the world, ozone concentrations have not. In many parts of the globe, short-term exposure to high levels of ozone has been linked to increased death rates and respiratory problems [6,12,29], Due to the difficulties in modelling ozone exposure and connecting individual exposures to health outcome data, the long-term impacts of ozone have received less attention than the short-term effects. Long-term ozone exposure has been linked to an elevated risk of respiratory death, according to [29]. Several studies also linked long-term ozone exposure to a worsening of lung function and the development of emphysema. The following studies confirmed that ozone had a great influence on respiratory health [6,28,29].

PM_{10}

There is compelling evidence that short-term exposure to PM_{10} causes respiratory difficulties, but $PM_{2.5}$ is a greater risk factor for mortality than the coarser PM_{10}, especially when exposure is prolonged [16]. Susceptible populations, such as those with a pre-existing heart condition, the elderly, and youngsters, are more vulnerable. Exposure to PM, for example, affects children's lung development, impairments in lung function and decreased overall lung growth, leading to a long-term lung function deficit [11]. Orellano et al., 2017). There is no evidence of a safe amount of exposure or a level below which there are no negative health consequences, from the studies reviewed. The fact that the exposure is both widespread and involuntary adds to the importance of this health factor. There is currently insufficient data to distinguish variations in the impacts of particles with diverse chemical compositions or originating from distinct sources at the population level. However, the evidence supporting the dangers of ignition PM is more robust than for PM from other sources. Numerous chemical compounds, including PM which are known carcinogens are now believed to play a role in health effects associated with black carbon in PM, especially respiratory health Schreiber [3,12,17].

NO_X

Inhaling air with a high concentration of nitrogen oxides can irritate an individual's respiratory system airways. Short-term exposures may aggravate respiratory illnesses, especially asthma, resulting in respiratory symptoms and hospital admissions. Exposure to higher nitrogen oxides for longer periods of time may influence the development of asthma. PM_{10} and ozone are formed when oxides of nitrogen (NO_x) and other hydrocarbon combine with other substances in the air. Both are toxic when breathed, owing to their impacts on the respiratory system. [12,17] showed how nitrogen oxides contribute to respiratory complications.

Effects of PM_{10}, O_3, and NO_X on Different Populations

Although ozone is linked with unfavorable health effects, little is documented about vulnerable groups or sensitive populations. However, a study conducted by [18] showed that children diagnosed with bronchiolitis and bronchopneumonia in 98 Homes in Lagos Nigeria were exposed to average concentrations of CO, SO_2, and benzene [18] added from the findings in their study using senior secondary school students, that cough and asthma are most frequently reported with more than 10% bronchitis prevalence from traffic and open burning air pollution. Also, [19] showed that particle matter exposure is more likely to harm those with heart or lung problems, children, and older individuals. Moreover, several studies reviewed those individuals with asthma, children, and the elderly, are at a higher risk of adverse health consequences from nitrogen oxides [14,20,21].

Previous Studies in Nigeria

Emissions from vehicles, solid waste incineration, and industrial pollutants all contribute to Nigeria's poor air quality, according to the WHO. Pollution levels in Nigeria vary seasonally according to the [22,23] WHO, (2014 & 2015) with the greatest levels occurring during Nigeria's dry season, which is usually from November to March. The cities of Onitsha, Umuahia, Kaduna, and Aba all have persistently serious air pollution [24]. Environmental health hazards are becoming a major issue in Nigeria as a result of a variety of environmental problems, including air pollution, flooding, water pollution, oil spills, erosion, deforestation, and desertification [25]. Significant environmental factors include ambient air pollution, home air pollution, and water, hygiene, and sanitation, all of which have been declining over an extended period of time [25]. In comparison, PM10 pollution, lead exposure, and ozone pollution all show a continuous increase in their association with mortality and disability-adjusted life years (DALYs) in Nigeria, suggesting a serious issue in an ecological health-related risk scenario. As a result, ecologically sustainable economic practices and policies should be considered critical for the public and policymakers to improve population health in Nigeria.

The discoveries of [26] contribute to the scant existing research on the detrimental respiratory health effects of ambient air pollution on city transport operators in certain Nigerian cities. Other

confounding variables working synergistically to produce a more severe and harmful impact are self-evident. The findings have significant policy implications aimed at decreasing urban ambient air pollution, including improved air quality management [26]. This may involve the creation of a central pollution management board, the monitoring of individual exposure in order to assess the health effects of air pollution, and the avoidance of construction in cities with high levels of air pollution.

Discussion

In 2012, air pollution claimed 3 million lives, accounting for 5.4 percent of all fatalities worldwide. In the same year, about 25 percent of respiratory infection fatalities were caused by lung cancer, 8 percent by chronic obstructive pulmonary disease (COPD), and approximately 18 percent by respiratory infection induced by air pollution [27]. According to one study, the effect of air pollution on premature deaths in Nigeria may double by 2050 [28] (Bauer et al., 2019). A 10μ/m-3 rise in PM10 resulted in a significant rise in COPD mortality and exacerbations that may be significantly decreased via air pollution management [17]. Cohort research in China found that the risks of death and years of life lost were directly related to the ambient concentrations of air pollution [16]. Therefore, to safeguard the respiratory public's health and individuals with chronic respiratory illnesses in Nigeria, the establishment of long-term regulations for ozone and PM should be considered.

Gaps in Literature

Only a few studies included critical analytic components, such as specific components that have been associated with a higher risk of disease/mortality compared to other chemicals found in these should be included in future research. Additionally, few studies included either of the three air pollutants (NO_X, O_3, and PM_{10}) in a single publication. Moreover, most papers did not do deep analyses of the effects of the pollutant on respiratory health. The few studies that accounted for the impact of the pollutants on respiratory health had very limited data on the population and pre-existing health conditions such as asthma. On a more positive note, some studies [4,6,12,16,17,28,29] examined the effects of NOX, O_3, and PM_{10} on respiratory health. However, none of these studies examined the effect of these pollutants (NO_X, O_3, and PM_{10}) o respiratory health patients in Nigeria.

Implications and Recommendation

As seen from this review, air pollution has the potential to harm the health of the general population, and be particularly harmful to children, the elderly, and people with pre-existing cardiovascular or respiratory conditions. Measures to decrease environmental air pollution should be considered. The arguments for action to decrease air pollution may take various forms, including urban planning, technical advancements (e.g. banning the use of leaded petrol, open burning, proper waste management, designing of lower emission cars), the implementation of warning systems, and new policies. This approach must operate at the population level in Nigeria, with precautionary policies, as well as at the interpersonal level, by educating and informing the vulnerable population about how to reduce their exposure to the discussed pollutants (O_3, PM_{10}, and NO_X). Some health advantages may be achieved at the population level in Nigeria by enacting particular policies, such as congestion charges in major cities and ending open solid waste burning. However, before spending large sums of public money on ineffective preventive initiatives, determining the impact on human health of exposure to major air contaminants in different states is crucial as different states suffer from different air pollutants in Nigeria such as the case of soot in Rivers state [29-32] Other frequent causes of pollution should also be considered such as living with a smoker, or open burning, for example, exposes a person to toxicant levels similar to those seen in a highly polluted city [33-49]. To safeguard the respiratory public's health and individuals with chronic respiratory illnesses in Nigeria, the establishment of long-term regulations for ozone and PM should be considered.

Conclusion

The findings of this study demonstrate the effect of O_3, PM and NO_x and how research activity is engaging with the global air pollution crisis. Additionally, the research activity reflects the degree to which Nigeria has responded responsibly to this global issue. NGOs should utilize such research to compel politicians and political campaigns in Nigeria to adopt environmental and industrial objectives aimed at improving air quality. Nations with high levels of air pollution and thus poor air quality should invest in research in this area to give health authorities a foundation for better action. Establishing national and regional research centers to monitor air quality and air pollution is critical to providing evidence for action. These institutes may bring together experts from various fields to cooperate on translating research findings into national goals and policies. At the national level, nations must implement stringent air quality standards. Industries and health authorities must collaborate to adopt steps that substantially decrease particulate matter, oxides of nitrogen, and ozone levels. Because air pollution is a worldwide hazard to public health, research collaborations between developed and developing countries with high levels of air pollution must be strengthened. Finally, since air pollution has a respiratory impact on the general public and especially those with underlying respiratory conditions such as COPD and asthma there is a need to educate and raise public knowledge about this problem.

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