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Impact Of Climate Change On Air Quality- A Review

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***Abstract:** Climate change is the modifications in meteorological variables (precipitation, temperature, humidity, mists and fogs) over a period of time and space due to human and sometimes natural causes. Climate change has direct effects due to weather phenomena or indirect effects which are due to the effects of pollutants on air quality. These eventually affect human, plant and ecosystem health .Some of the disorders include lung irritations, respiratory problems and the aggravation of cardiovascular disorders. Added to the health effects on humans are the corrosive acid rain and its effects on plants and the ecosystem. The status of air quality and human health are closely related because as Changes in weather that accompany climate change affect atmospheric concentrations of pollutants thereby changing air quality which consequently affects health.*

This review focuses on the manner in which changes in climate variables such as temperature, precipitation, humidity, seasonal variation in the emissions of volatile organic compounds (VOCs), sulphur oxides (SO_x), and nitrogen oxides (NO_x) affect air quality. Of particular concerns are potential changes in tropospheric ozone radicals and particulate matter. In this review, particular effort was be made to highlight literature relating to air pollutants, monitoring, modeling and forecasting of air pollutant levels, impact on health of air pollutants, the vulnerability to air pollution and strategies for adaptation to air pollution.

***Keywords:** Climate change, Air quality, Air pollution, Adaptation strategies*

I. INTRODUCTION

Climate change is a worldwide problem and every nation is making concerted effort to formulate specific answers and solutions to it. The atmospheric science community recognizes that climate and air quality are linked through atmospheric chemicals, radioactive and dynamic processes on multiple scales (NRC, 2001). The results of a number of studies on the relationship between weather and ozone concentrations, the effects of temperature on atmospheric chemistry and the sensitivity of emission to weather and land use suggest that climate change could adversely affect air quality (USEPA, 1996). Human beings, agriculture, animals and the environment are exposed to climate change through changing weather patterns (temperature, precipitation, sea level rise and frequent extreme events) and indirectly, through changes in water, air, food quality and changes in ecosystems, agriculture, industry, settlements and the economy.

The atmosphere has always been a sink (for deposition and storage) for gaseous or particulate wastes. When the amount of waste entering the atmosphere in an area exceeds the ability of the atmosphere to disperse or degrade the pollutants, problems result (Botkin and Keller, 1995). According to Penner *et al.* (1989); US EPA (2003), Changes in circulation and precipitation patterns affect the transport of acidic materials, which determine the geographical location of acid deposition.

NRC, (1991) has it that in general, an increase in atmospheric temperature accelerates photochemical reaction rates in the atmosphere and increases the rate at which troposphere ozone (O_3) and other oxidants (e.g. hydroxyl radicals) are produced. In addition Mukammal *et al.*, (1982), postulated that ozone is expected to be influenced by wind speed because lower wind speed could lead to reduced ventilation and the potential for greater build up of O_3 and its precursors.

The earth is getting warmer, and scientists conducting research on global climate change overwhelmingly agree that most of the warming since the mid 20th century has been caused by humans, primarily through the burning of fossil fuels such as coal and petroleum. Climate model projections suggest that average global temperatures could increase from 3 to 10 degrees Fahrenheit by the year 2100. This reflects the amount of carbon dioxide and other greenhouse gases that might actually be put into the air.

Developing a strategy for adaptation to climate change would be used as an opportunity to plan broadly for a sustainable prosperity, by designing and planning for land use, transportation systems, disaster management, and reducing carbon footprint.

II. CLIMATE CHANGE, AIR QUALITY AND DISPERSION OF AIR POLLUTANTS

Climate change could affect local or regional air quality through changes in chemical reaction rates, boundary layer heights that affect vertical mixing of pollutants, and changes in airflow patterns that govern pollutant transport.

Temperature is a decisive meteorological variable for regional climate and air quality. A Temperature change can result in a change in atmospheric and oceanic circulations (Zorita *et al.*, 1992), precipitation (Houghton et al. 2001), extreme weather events (Emanuel 2005), etc. These can lead to air quality changes.

In addition, Botkin and Keller, (1995), observed that high wind speed increases the rate of dispersal of air pollutants. Increase in water vapour and temperature increase the potential for ozone formation. Precipitation (rainfall) cleans the air, but when NO_x and SO_x in the atmosphere react to form nitric and sulfuric acids, acid rain results. Air pollutants may also have significant effects on concentrations of carbon dioxide and methane. Botkin and Keller, (1995) also implied that rising sea levels (another outcome of global warming) increases the risk of coastal flooding and could cause population displacement. Flooding can directly cause injury and death, and increase the risk of infection from water and vector borne disease. Mahmud *et al.* (2008) stated further that temperature is a crucial factor for the formation of some pollutants, such as ozone.

According to Costa, (2011), the interrelationship between climate and air quality is highly dynamic. On one hand, air quality is dramatically influenced by climate parameters; like higher temperatures and altered constituents of air can increase ozone levels in some localities.

III. CLIMATE CHANGE AND PUBLIC HEALTH

According to CDC, (2012), climate change affects air quality through several pathways including the production and allergenicity of aeroallergens such as pollen and mold spores; and increases in regional ambient concentrations of ozone, fine particles, and dust. Some of these pollutants can directly cause respiratory disease or exacerbate existing respiratory diseases in individuals.

There is also a possibility that certain aeroallergens may become more allergenic as temperatures and CO_2 concentrations increase. CDC, (2012) also stated that precipitation affects aeroallergens such as mold spores. Also of concern, is the fact that 5% of individuals are predicted to have some form of respiratory allergic airway symptoms from molds (Brunekreef, 2002).

CDC, 2012, stated that in the presence of certain air emissions, the rate of ozone formation increases with higher temperatures and increased sunlight. This can also be affected by changes in storm tracks, humidity, and stability of the boundary layer (lowest part of the atmosphere) humidity and temperature also partly determine the formation of PM. Research studies by CDC, 2012 link fine particles to heart attacks, formation of deep vein blood clots, and increased mortality from several other causes. These adverse health impacts intensify as temperatures rise. WHO (2000) and Ebi and McGregor (2008) suggested that because the state of the atmosphere determines the development, transport, dispersion, and deposition of air pollutants, there is concern that climate change could affect morbidity and mortality associated with elevated concentrations of the pollutants and fine particles. Extensive literature like Salvi *et al.* (2012); WHO, (2000) and USAID, (2007), document the adverse health impacts of exposure to elevated concentrations of air pollutants, particularly ozone, particulate matter (PM) with aerodynamic diameters <10 (PM_{10}) and < 2.5 µm ($PM_{2.5}$), sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead.

CDC, (2012) also noted that weather and climate have affected human health for millennia. Climate change is altering weather and climate patterns that previously have been relatively stable. Climate experts are particularly emphatic that climate change will bring increasingly frequent and severe heat waves and extreme weather events, as well as a rise in sea levels. These changes have the potential to affect human health in several direct and indirect ways. Heat exposure as a result of increase in temperature has a range of health effects, from mild heat rashes to deadly heat stroke. Heat exposure can also aggravate several chronic diseases, including cardiovascular and respiratory diseases. Heat also increases ground-level ozone concentrations, causing direct lung injury and increasing the severity of respiratory diseases such as asthma and chronic obstructive pulmonary disease.

The direct effects of extreme weather events include drowning and injuries from floods, and structural collapse. Indirect effects outnumber the direct effects and likely will be more costly. Potential indirect effects include aggravation of chronic diseases due to interruptions in health care service, significant mental health concerns both from interrupted care and geographic displacement, and socioeconomic disruption resulting from population displacement, infrastructure loss and loss in livelihoods (Ebi and McGregor, 2008b).

Urban air pollution causes serious health problems. Motor vehicle emissions seem to be the dominant source of air pollutants especially in areas with high traffic densities and industrial activities. In recent years, public concern has increased due to wide publicity about the damage to human health from inhaling gaseous pollutants and fine particulates (Botkin and Keller, 1995). It has also been suggested that high incidences of respiratory health in urban areas may be associated with inhaling noxious gases and particulates in the air. According to Pope III, (2004), many of the pollutants have synergistic effects; the combined effects being greater than the sum of separate effect. For example sulfate and nitrate may attach to small particles in the air, facilitating their inhalation deep into lung tissue, where greater damage to the lungs may occur than is attributable to either of these pollutants alone (Botkin and Keller, 1995).

Response to air pollution problem varies from country to country. Odhiambo *et al*., (2010), noted that unlike the industrialized countries where much research has been done, little seems to have been done in developing countries, especially in Africa with regard to motor vehicle air pollution.

Black carbon is a key component of particulate matter which is the main contributor to the health impacts of air pollution, causing the premature deaths of hundreds of thousands of people each year. Compared to carbon dioxide, these substances live for a short time in the atmosphere, anything from a few days or weeks for ozone and black carbon, to a decade for methane. Kuylenstierna and Hicks, (2008) suggested that urgent action to decrease their concentrations in the atmosphere will improve air quality (reducing risks to health and crop yields). It would also combat short-term accelerated warming thereby reducing risks of crossing critical temperature and environmental thresholds.

IV. MONITORING CLIMATE CHANGE

Quezada *et al*., (2012) opined that in order to understand local climate better and thus be able to develop scenarios for climate change, they must have adequate operational systematic observing networks, and access to the data available from other global and regional networks. These systems enable the integration of national early warning systems, Geographical information system (GIS) mapping of vulnerable areas, meteorological information on flooding and droughts, as well as the mapping of disease outbreaks. In this way, indicators for monitoring the impacts of climate change to facilitate disaster preparedness and adaptation planning are provided.

A climate change monitoring system integrates satellite observations, ground-based data and forecast models to monitor and forecast changes in the weather and climate. A historical record of spot measurements is built up over time, which provides the data to enable statistical analysis and the identification of mean values, trends and variations. The better the information available, the more the climate can be understood and the more accurately future conditions can be assessed, at the local, regional, national and global levels. This has become particularly important in the context of climate change, as climate variability increases and historical patterns shift (Quezada *et al*., 2012).

Systematic observation of the climate system is usually carried out by national meteorological centres and other specialized bodies (Quezada *et al*., 2012). They take measurements, make observations at standard preset times and places, and monitor the atmosphere, ocean and terrestrial systems. National monitoring systems forms part of a global network. They ensure that there is consistency as possible in the way measurements and observations are made. This includes accuracy, the variables measured and the units they are measured in. According to Quezada *et al*., (2012), the World Meteorological Organization (WMO) performs a vital role in this respect. The National Meteorological or Hydro meteorological Services (NMHS) of 189 member states and territories form the membership of the WMO. This enables them to establish and promote best practice in national climate monitoring.

Quezada *et al*., (2012) also highlighted some of the climate monitoring systems and they include; Global Climate Observing System (GCOS), Biological indicators, Climate Impact on Agriculture (CLIMPAG), FAO- Modeling system for agricultural impact of climate change (FAO-MOSAICC).

A. GLOBAL CLIMATE OBSERVING SYSTEM (GCOS)

The Global Climate Observing System (GCOS) was established in 1992 to provide comprehensive information on the total climate system, involving a multidisciplinary range of physical, chemical and biological properties; and atmospheric, oceanic, hydrological, cryospheric and terrestrial processes which ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users (Quezada et al., 2012). As a system of climate-relevant observing systems, it constitutes, in aggregate, the climate observing component of the Global Earth Observation System of Systems (GEOSS). As part of its role to provide vital and continuous support to the United Nations Framework Convention on Climate Change (UNFCCC), GCOS has established 20 Climate Monitoring Principles, as well as defined 50 Essential Climate Variables (ECVs). Surface atmospheric conditions are the most straightforward of the ECVs to measure. Accurate measurements can be taken using relatively simple equipment.

B. BIOLOGICAL INDICATORS OF CLIMATE CHANGE

Developed over years of observation and experience, bio-indicators form an essential part of community strategies for disaster risk reduction and climate change adaptation. In terms of development benefits, ancestral bio-indicators enable farmers to maintain productive farming practices and even to take advantage of changes in climate where this leads to longer periods of suitable weather for crop cultivation, or where they are able to adjust crop type to benefit from new climate conditions (Alvarez and Vilca, 2008). Traditional forecasting methodologies incorporate local observations of climatic and other environmental changes or bio-indicators into social organization to provide an early warning mechanism for hydro-meteorological phenomena that appear suddenly or over time. According to Quezeda *et al*., (2012), environmental bio-indicators of climate change include changes in the behaviour of animals (for example migration and mating seasons), of plants (such as changes in hydrological tolerance, flowing periods and changes in ecosystem composition) and of weather conditions (such as longer, drier periods, increased frequency of cold periods).

Alvarez and Vilca, (2008), noted that forecasting with ancestral bio-indicators can be considered an adaptation technology because studies show that they are complementary to climate predictions issued by national meteorological services. In many cases, bio-indicators are more effective for local-level response and adaptation strategies as they provide a more immediate diagnosis than meteorological warnings issues by centralized state entities and are also more adapted to predicting conditions at the local level Alvarez and Vilca, (2008) concluded.

According to Guralnick, (2002), Biological indicators are the subject of scientific research, with studies being conducted into organisms including fish, insects, algae, plants and birds and their role as a form of early detection of El Niño Southern Oscillation (ENSO) events. Rural farmers have learned to observe local bio-indicators as a basis for making strategic decisions about their agricultural production. One such strategy is the observation of certain bio-indicators (e.g butter flies and budding trees) several months before sowing and during the crop growth cycle in order to make weather forecasts and predictions and adjust planting and cultivation activities accordingly.

According to Hambly and Onweng (1996), in the Kwale District in Kenya, the end of seasons can be predicted by migration of a specific type of monkey, movement of butterflies and budding of some trees. All of these alert the community to prepare the land. The start of the rains is predicted by the change in winds flowing towards the North, the changes in the position of stars and information given by fishermen on the ‘mixing’ (inversion) of sea water.

In Zimbabwe, interviews with community members captured information on how certain types of trees, birds and some patterns of animal behaviour have, for many years, been used as measures or signals of changes in the quality of their environment. These include: trees as soil fertility indicators, birds as heralds of the rainy season, trees as water level indicators, and abundance of wild fruits as indicators of good rainy season. This approach promotes the active participation of community meteorological observers who keep daily records of local bio-indicators and climate variables captured by basic weather stations installed on their farms. They screen the information, hand over the data to system operators for processing and validation, produce and disseminate weather forecasts and provide guidance and advice (such as on the type of crops or the farming schedule) to their communities in the native language. This model promotes decentralized participatory data collection and monitoring processes which can empower communities to make collective decisions about their livelihood strategies, Hambly and Owen, 1996 concluded.

C. CLIMPAG SYSTEM

Kuika *et al*., (2011) studied Climpag (Climate Impact on Agriculture) which is aimed at bringing together information on interactions between weather, climate and agriculture in the general context of food security. The programme has developed practical methodologies and tools to help increase understanding of and aid analysis of the effect of the variability of weather and climate on agriculture. One of these tools is agrometeorological crop forecasting that is used to estimate crop yields and production usually a couple of months before the harvest takes place. The FAO approach uses computer models that attempt to simulate plant-weather-soil interactions. Key factors that affect crop yields are fed into the model, which then produces outputs such as maps of crop conditions and yields. Weather data is among the most important data that condition the inter-annual variability of crop yields; and are thus an essential crop forecasting input. Other inputs include the ‘crop calendar’, crop reports, satellite-based variables such as Normalised Difference Vegetation Index (NDVI) and Cold Cloud Duration (CCD), others are factors such as technology, management, prices and government policies and reference data. Detailed information about crop stages - also known as the "crop calendar" - play an essential role in crop monitoring and forecasting. This is because the effect of environmental conditions on crops depends very much on crop growth stages. For instance, water requirements are normally low at the initial growth stages, while they reach a maximum just after flowering.

D. FAO-MOSAICC SYSTEM

FAO-MOSAICC (Modeling System for Agricultural Impacts of Climate Change) integrates four models related to (statistical) downscaling global circulation model data, hydrology, crop growth and assessing impacts of crop yields on national economies (Rutan, 1994). According to Kuika *et al*., (2011), the objective of the system is to assess the impacts of changing crop yields on national economies in order to develop effective adaptation strategies.

V. MODELING AND FORECASTING OF CLIMATE CHANGE

Climate models are systems of differential equations based on the basic laws of physics, fluid Mechanics and chemistry. To “run” a model and forecasting of climate change, scientists divide the planet into a 3-dimensional grid, apply the basic equations, and evaluate the results.

According to Gardener, (2010), various types of climate models exist. Some focus on certain things that affect climate such as the atmosphere or the oceans. Models that look at few variables of the climate system may be simple enough to run on a personal computer. Other models take into account many factors of the atmosphere, biosphere, geosphere, hydrosphere, and cryosphere to model the entire Earth system. They take into account the interactions and feedbacks between these different parts of the planet.. In general, the more complex a

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model, the more factors it takes into account and the fewer assumptions it makes.

Gardner (2010) also stated that at the National Center for Atmospheric Research (NCAR), researchers work with complex models of the Earth's climate system. The most robust models are compared by the IPCC (Intergovernmental Panel on Climate Change) as they summarize predictions about future climate change.

In addition, Pope, (2007) stated that climate models are used to reproduce the climate of the recent past, both in terms of the average and variations in space and time. They are used to reproduce what we know about ancient climates (which are more limited).

The Met Office Hadley Centre model is unique among climate models in that it is used with more regional detail to produce the weather forecasts every day. IPPC, (2001); Pope, (2007); and Wikipedia, 2012, identified the major climatic models as follows:

A. GENERAL CIRCULATION MODEL (GCM)

General Circulation Models (GCMs) are a class of computer-driven models for weather forecasting, understanding climate and projecting climate change. Atmospheric and oceanic GCMs (AGCM and OGCM) are key components of global climate models along with sea ice and land-surface model. In a study by Sun and Hansen, (2003), AGCMs were found to consist of a dynamical core which integrates the equations of fluid motion, typically for surface pressure, horizontal components of velocity in layers, temperature and water vapor in layers. All modern AGCMs include parameterizations for convection land surface processes, albedo and hydrology cloud cover.

A GCM contains a number of prognostic equations that are stepped forward in time (typically winds, temperature, moisture, and surface pressure) together with a number of diagnostic equations that are evaluated from the simultaneous values of the variables. Oceanic GCMs (OGCMs) model the ocean (with fluxes from the atmosphere imposed) and may or may not contain a sea ice model.

B. COUPLED ATMOSPHERE-OCEAN GENERAL CIRCULATION MODELS (AOGCM)

The most complex climate models, the coupled atmosphere-ocean general circulation models (AOGM), involve coupling the atmospheric general circulation models (AGCMs), with ocean general circulation models (OGCMs), with sea-ice models, and with models of land-surface processes. For AOGCMs, information about the state of the atmosphere and the ocean adjacent to, or at the sea surface, is used to compute exchanges of heat, moisture and momentum between the two components. AOGCMs are the only models that can provide detailed regional predictions of future climate change. According to Donnor et al., (2011), Coupled atmosphere–ocean GCMs (AOGCMs) (e.g. Hadley Centre Coupled Model, version 3 (HadCM3), Geophysical Fluid Dynamics Laboratory Circulation Model version3 (GFDL CM3.X), combines the Atmospheric and oceanic models. These models address emerging issues in climate change, including aerosol–cloud interactions, chemistry–climate interactions, and coupling between the troposphere and stratosphere.

C. ATMOSPHERIC MODEL (AM)

According to Donnor *et al.*, (2011) atmospheric models calculate winds, heat transfer, radiation, relative humidity, and surface hydrology within each grid and evaluate interactions with neighboring points. The winds, heat transfer and other quantities are only used to compute a final result. So they do not need to correspond to real world conditions, and in some numerical schemes fictitious quantities are introduced.

D. SIMPLE MODELS

Simple models allow one to explore the potential sensitivity of the climate to a particular process over a wide range of parameters. Simple climate model rely on climate sensitivity and ocean heat uptake parameters based on coupled atmosphere-ocean models and ice-melt parameters based upon more complex ice sheet and glacier models. They are also used within larger integrated assessment models to analyze the costs of emission reduction and impacts of climate change (Donnor *et al.*, 2011).

VI. VULNERABILITY TO CLIMATE CHANGE

Vulnerability to the impacts of climate change is a function of exposure to climate variables, sensitivity to those variables, and the adaptive capacity of the affected person or community (USAID, 2007). The consequences of climate variability and climate change are potentially more significant among the poor in developing countries than those living in more prosperous nations. Often, the poor are dependent on economic activities that are sensitive to the climate. For example, agriculture and forestry activities depend on local weather and climate conditions; a change in those conditions could directly impact productivity levels and diminish income. According to USAID, 2007; IPCC, sectors directly or indirectly vulnerable to climate change are agriculture, ecosystems, water resources, human health industry and society.

In the study of Adesina *et al.*, (2008), specific vulnerabilities and impacts pertaining to climate change include declining volumes of water in reservoirs and stream flows, coastal flooding by ocean water, land bound storms from Atlantic ocean, crop failures due to frequent dry spells during growing seasons, menace of aquatic weeds, shortage of fodder, increasing conflicts between farmers and herdsmen, deforestation and desertification. The indirect vulnerability issues relate to the sprawling of settlements unto rural land, poor energy production, low industrial activities, poorly developed transportation system, challenges relating to human health and gender issues.

A. STRATEGIES FOR ADAPTATION TO CLIMATE CHANGE

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Curry, (2012), stated that the problem of the increasing carbon dioxide in the air is global, but that the consequences of climate change are entirely local. Communities and local and state governments are now paying more attention to adaptation strategies. Adaptation refers to changes in natural or human systems that moderate harm or exploit opportunities.

California Department of Public Health, (2008) and Shea et al, (2008), suggested that the main public health responses to the projected health impacts of climate change are mitigation and adaptation. Policies and strategies to adapt to the health impacts from exposure to air pollutants include:

- ✓ Monitoring Air Quality Index (AQI) days as part of the emergency response plan by Creating pre-scripted messaging around strategies to stay safe, e.g. reducing outdoor activity and therefore exposure; and providing guidance and education on how to locate and interpret daily air quality indices and pollen counts. Expanding dissemination of climate change impact information on benefits of mitigation strategies, and preparedness strategies to engage vulnerable communities and outreach to tribal nations, private and health sector.
- ✓ Dissemination of information to address specific risks associated with climate change (e.g., to prevent heat illness in communities and in workplaces, vector-borne or food-borne diseases, etc.)
- ✓ Dissemination of information specific to vulnerable populations (e.g., outdoor workers and residents in urban heat islands or people with chronic illness regarding heat, immigrants with literacy/language needs)
- ✓ Make available educational materials in multiple languages to reach wider audiences
- ✓ Formally engage the full community in planning and preparing for an effective disaster response, as well as climate change mitigation and adaptation. It is especially critical that efforts are made to engage the most vulnerable segments of the community in this planning. This could help to fortify community mental health in advance of a disaster or the changes required for mitigation or adaptation.
- ✓ Carry out surveillance of health conditions related to climate change, including improved public health tracking of asthma and allergic disease
- ✓ Utilize only low allergenic pollen producing plants for landscaping (conduct a citywide tree inventory and evaluate surrounding pollen and climate conditions to determine whether regulations on planting can actually influence pollen levels

Current scientific evidence like Jones (2005, shows that air pollution and climate change policies must be integrated now to achieve sustainable development and a low carbon society.

Today, the absence of sooty urban air and the presence of clear vistas are the visible hallmarks of successful air pollution policies. Jones (2005) also revealed that indeed, in the last two decades, the percentage of people who view the threat of air pollution with “a great deal of concern” has been reduced by 25%.

Ostro et al., (2006) observed that adaptation is not an effective risk management strategy for poor air quality, because physiologic mechanisms to reduce susceptibility to ozone and other air pollutants are limited. Therefore, if improved model experiments continue to project higher ozone concentrations under a changing climate, rapid reductions of emissions from fossil-fuel burning are needed to protect the health of current and future generations. Evidence suggests that reducing current troposphere ozone concentrations reduces morbidity and mortality, with significant savings in medical care costs.

For relevant agencies and institutions to develop appropriate and timely responses, additional research is needed to reduce the uncertainties associated with projections of the health impacts of changing concentrations of ozone and PM due to climate change. Research is needed to better understand the impacts of future emissions pathways, climate change impacts on concentrations of fine particles and gases, and how changing weather patterns could influence the frequency and severity episodes of poor air quality, population sensitivity, and how these factors might interact. According to Ebi and McGregor, (2008), increasing greenhouse gas emissions suggest that future air quality could decline without increased regulations and development and deployment of new technologies.

VII. CONCLUSION

Strategies and measures recommended for adaptation to climate change and the reduction of emissions will benefit the environment through improved air and water quality, improvements to the urban traffic problems, more reliable water supply, greater resilience to weather disasters, and lower energy costs. Investments made in a more sustainable environment and reductions in vulnerability to climate change are investments in sustainable prosperity and economic growth.

The adoption of readily available measures to lower emissions from power plants and automobiles would provide major public health benefits by improving air quality. Doing the tries suggested by Minnesota Climate and Health Program, (2012), that effective policies to mitigate health impacts from exposure to air pollutants would require a focus on the reduction of emissions.

VIII. RECOMMENDATIONS

- ✓ Climate change and air pollution are trans-boundary problem, and perhaps require transnational involvement in combating them.
- ✓ An integrated effort is required for reducing the concentrations of methane, ground-level ozone and black carbon as well as CO_2 emission cuts. Ozone reductions are best achieved by cutting emissions of all precursors like nitrogen oxides, volatile organic compounds, and methane.
- ✓ Cost-effective options need to be prioritized because opportunities for reducing emissions of methane and other ozone precursors in industry, agriculture, mining and transport are widely available and relatively inexpensive.

Achieving the reductions of air pollutants require extensive commitment at regional and global levels.

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