LINEAR ECONOMIC GROWTH, EXPONENTIAL AIR POLLUTION

Sean Edward Paquette
Rensselaer Polytechnic Institute – Hartford, Connecticut
MANE – 6960H01 (Air and Water Pollution Prevention and Control Engineering)
Professor Ernesto Gutierrez-Miravete, Ph.D.
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Course Policy: Research Projects

Each student will be responsible for the performance and production of two reports of individual research work. One report will be on air pollution, and the other on water pollution. The goal of these research projects is to demonstrate grasp of selected air and water pollution problems or systems, the ability to describe and clearly explain the key elements in each case, to quantify whenever appropriate and reach and summarize conclusions including recommendations for action from a pollution prevention/waste minimization perspective. Topics for the air pollution project must be selected and approved by the instructor by the second week of class and for the water pollution project by the eight week of class and officially submitted in the form of a short proposal. Suitable research project topics can be derived from careful review of the course textbooks, from a detailed review of current literature, from a student-related interest or from an instructor suggested problem. Report should be brief but comprehensive (~10-12 pages) and prepared in a professional format (cover page, table of contents, various sections, conclusions and references).

Air Pollution Focus (Approved by Professor)

The world’s current population is estimated to be about 7 billion people and is expected to grow to about 9 billion people by year 2040. A majority of the population growth will be focused in urban areas making it challenging to improve air quality at a rate better or equal to the population growth. In the past as countries and cities grew they focused all efforts on economic development and none on the environmental concerns. Today, as countries continue to grow and develop due to the exponential expected population growth there needs to be more resources focusing on the environmental concerns not only job/population development. This research paper will focus on air quality in relationship to economic development specially, population growth in urban areas of China.

Air Pollution Problem Statement (Approved by Professor)

How does economic growth effect air quality throughout China? By what means can urban air pollution be reduced in developing countries?
Linear Economic Growth, Exponential Air Pollution

The Effects of Economic Growth on Air Pollution

Sean Edward Paquette
Rensselaer Polytechnic Institute – Hartford, Connecticut
MANE – 6960H01 (Air and Water Pollution Prevention and Control Engineering)
Professor Ernesto Gutierrez-Miravete, Ph.D.
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Abstract: Air pollution poses enormous health risks to billions of people around the world every day, contributing to heart disease, lung failure along with many other fatal human illnesses and diseases. Managing air pollution is critical to human, economic and environmental growth in communities throughout the world today. Currently, the total world population is estimated around 7 billion people and is expected to grow beyond 9 billion people by the year 2040. This paper examines air quality related to economic growth and studies different techniques to reduce urban air pollution in developing countries without slowing gross domestic product growth.

Keywords: Air Pollution; Economic Growth; Environmental Sustainability; CO; SO₂; N₂O; PM₁₀

I. INTRODUCTION

The world’s current population is estimated to be more than 7 billion people and is expected to grow beyond 9 billion people by the year 2040, according to the Exxon Mobil 2013 Outlook for Energy: A View to 2040 (Reference (1), Appendix A). Appendix (A) is a comparison between the world population in 2010 and the projected world population in 2040. A majority of the population growth will reside in urban areas making air pollution challenging to improve air quality at a rate better or equal to the population growth. By the year 2040, 75%[1] of the world’s population will be located in Asia Pacific and Africa. As cities and countries around the world grow they focus entirely on economic growth, increasing both production and consumption of goods and services, rather than environmental
sustainability. Environmental sustainability, “seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans.”[2] Air pollution is a major characteristic for forming a sustainable world with continual economic growth. Air pollution is generally used as a quantitative gauge for the quality of the atmosphere. This research paper focuses on air quality as a result of economic growth and examines different techniques to reduce urban air pollution in developing countries without slowing the nation’s gross domestic product (GDP) growth. In this report GDP is, “the sum of the final uses of goods and services measured in purchasers’ prices, less the value of imports of goods and services.”[3] The geographical region this report examines is Asia Pacific as the majority of the population growth over the next three decades is increasingly concentrated in China and India. The quantitative statistics and models composed in this report use data collected on China to examine, while the theories and techniques throughout this report can be applied to any country in the world.

This paper is organized as follows: Section 2 provides a detailed report of air pollution in China. Section 3 summarizes air quality in relationship to economic growth. Section 4 examines different techniques and innovative technologies to reduce urban air pollution, followed by a summary of results in Section 5.

II. AIR POLLUTION

Air pollution, both indoors and outdoors, pose health risks to billions of people every day. United States Environmental Protection Agency (EPA) defines air pollution as, “one or more chemicals or substances in high enough concentrations in the air to harm humans,
animals and vegetation. Such chemicals or physical conditions (such as excess heat or noise) are called air pollutants.\textsuperscript{4} China is presently the largest emitter of greenhouse gases (GHGs) in the world. GHGs defined as various gaseous compounds that trap heat in the atmosphere, absorb infrared radiation and contribute to the greenhouse effect. Shanghai is the most economically developed city and is currently categorized as the sixth worst city for air pollution in China, (Appendix B). Appendix (B) is a bar graph showing cities with the worst outdoor pollution in India and China.

Over the past decade air pollution in China has significantly increased in all cities, specifically cities with major economic growth. Every day air quality poses an immediate threat to the environment with increasing visible and nonvisible air pollutants. Four fundamental air pollutants studied in this report are carbon monoxide, sulfur dioxide, particulate matter and nitrogen dioxide.

CO is the chemical formula for Carbon Monoxide (CO), a poisonous, colorless, odorless gas. CO is produced by, “the incomplete burning of various fuels, including coal, wood, charcoal, oil, kerosene, propane, and natural gas.”\textsuperscript{5} Products and equipment powered by internal combustion engines also produce CO. The core sources of excess CO are motor vehicle exhaust and industrial activities. The natural amount of CO that is not harmful to humans is 0.2\textsuperscript{6} parts per million (ppm). The average CO concentration ranging between 1 ppm to 70 ppm will have minimal if any negative health effects on humans with prolonged exposure. As CO concentration increases to the ranges of 70ppm and 200ppm human health
symptoms develop and worsen with prolonged exposure varying from headaches, fatigue and even leading to death.

Sulfur dioxide, also known scientifically as (SO$_2$) is another highly reactive, poisonous, nonflammable, water soluble and colorless gas. SO$_2$ is produced from burning coal, oil and other similar fossil fuels along with the smelting of mineral ores. The largest source of SO$_2$ emissions originates from the combustion of coal in large power plants, 73% according to the US Environmental Protection Agency. Others sources releasing SO$_2$ into the atmosphere are locomotives, construction diesel equipment, large transport ships, tobacco smoke, and alongside a number of other inadequately vented gas and oil appliances. Furthermore, SO$_2$ is a major component in acid rain.

Particulate matter is a major concern in the Asia pacific countries. Particulate matter (PM$_{10}$) and (PM$_{2.5}$) are solid or liquid particles emitted into the air. For example, particulate matter is the black smoke from a vehicle’s exhaust pipe or the ash from a fire. Particulate matter is measured in two sizes PM$_{10}$ and PM$_{2.5}$. PM$_{10}$ is particulate matter 10 microns in diameter or less, PM$_{10}$ has been monitored since the late 1970’s. PM$_{10}$ particles when inhaled accumulate in the respiratory system and can potentially cause harmful damage. In the last decade, PM$_{2.5}$ recently began being measured and recorded. PM$_{2.5}$ are particles 2.5 microns in diameter or smaller (about 1/10,000 of an inch). PM$_{2.5}$ particles are small enough to pass through the respiratory track and into the bloodstream. Appendix (C) is a comparison of particulate matter size.
Another air pollutant examined in this report is nitrogen dioxide (NO\textsubscript{2}). NO\textsubscript{2} is a “toxic reddish brown gas that is a strong oxidizing agent”\textsuperscript{8} and is produced by combustion of fossil fuels. Sources of NO\textsubscript{2} include tobacco smoke, un-vented gas, kerosene stoves and heaters. Furthermore, cars, trucks and off-road heavy equipment are sources of NO\textsubscript{2} emissions. High doses of NO\textsubscript{2} can potentially cause pulmonary edema as well as lung damage.

III. RELATIONSHIP BETWEEN ECONOMIC GROWTH AND AIR POLLUTION

China in 1978 shifted from a centrally planned economy to a market based economy. For decades, China’s rapid economic growth brought on many difficult challenges, including high inequality, rapid urbanization and extreme environmental sustainability problems. Even though recently China’s 2013 GDP decreased to 7.7\textsuperscript{10}, over the previous 40 years China’s GDP grew from 5\textsuperscript{11} to over 10.4\textsuperscript{11}. Figure (1) below is a display illustrating the trend of China’s GDP growth between 2010 and the first quarter of 2013. While figure (2), is a graph illustrating China’s annual GDP growth between 1960 and 2010. Currently, China with a population of 1.4 billion\textsuperscript{9} is the second largest economy in the world and ranked number one for the most polluted country in the world.
According to an article in Foreign Policy, economic growth in China is expected to continue climbing with nebulous concern for air pollution and other environmental issues. In the year 2040, “the Chinese economy will reach $123 trillion, or nearly three times the economic output of the entire globe in 2000.” Although, the Chinese per capita wealth ($85,000/per capita) will not overtake the United States, China, will be responsible for 40% of the total world’s GDP compared to the 14% contributed by the United States. Furthermore, “a recent study by Carnegie Endowment for International Peace predicts that by 2050, China’s economy will be 20% larger than that of the United States.”
Decades of economic growth and prosperity have led to dangerous levels of hazardous smog, including air pollutants such as carbon monoxide, sulfur dioxide, particulate matter and nitrogen dioxide. The current levels of air pollution are mainly caused by emissions produced from increasing number of power plants, vehicles and other human activities. China’s total energy consumption increased 7 times in 34 years due to rapid economic growth. As a result, China enough power plants to accommodate their economic demand. Due to the abundant amounts of coal, in China, coal currently is and will remain the fossil fuel of choice. Appendix (D) is an illustration of China’s energy demand between 1970 and 2020. Fossil fuel power plants supplying the large demand of electricity and the increase in personal transportation are the two leading causes for an extreme increase in CO, SO₂, PM₁₀, PM₂.₅ and NO₂ emissions in China. Figure (3) below is another graphic illustrating the daily increase of PM₁₀ over a 10 year period recorded at nine different stations throughout China.

![Graph showing PM₁₀ Concentrations](image)

*Figure 3: Daily PM₁₀ Concentrations between 2001 and 2010*
Furthermore, a third example of the air pollution increase in China related to rapid economic growth is from a recent study of overcast versus cloud-free days in China facilitated by the U.S. Department of Energy’s Pacific Northwest National Laboratory, which stated that

“The amount of sunlight reaching the ground at 500 measurement stations in China fell dramatically between 1954 and 2001. This decline in solar radiation, which averaged 4.43 watts a square meter per decade, occurred despite an overall decrease in China’s cloud cover over the study period.” (Reference 13)

Figure (4) below is a graph summary and forecast of SO₂, NO₂, CO₂ and mercury discharge levels increasing from 1995 to 2020 from an article titled, “Controlling Air Pollution from Coal Power Plants in China: Incremental Change or a Great Leap Forward,” Environmental Science & Technology Journal.

![Figure 4: Discharge in China between 1995 and 2010](image)
IV. AIR POLLUTION REDUCTION

As the health conditions of China’s population and environment are negatively impacted due to the rapid economic growth and primary use of fossil fuels, incremental forward process can be made through new techniques and innovative technologies to reduce air pollution. The most efficient methods to help reduce and keep the environment clean is to move to an individual basis, with industry and government incentives. For example, the number of vehicles on the roads in China has increased proportional with the country’s population and economic growth. The second, most accountable source for a large portion of air pollution is vehicle engines emissions. Therefore, a method to reduce air pollution can begin with independent companies designing and engineering vehicles to a more sustainable environmental standard and being incentivized by the government. Innovative technologies such as bio-filtration systems for large power plants releasing off-gases containing hazardous air toxics should continue to be developed and applied to power plants throughout the world. New forms of public transportation need to be built with equipment with less of a pollution output. Moreover, alternative fuel sources, for example nuclear power and natural gas need to replace the coal power plants laterally with government tracking power plant efficiencies and emission standards.

V. SUMMARY

This report demonstrated China’s poor air quality and discussed contributing factors. China will continue to be drastically effected by the tremendous economic growth. Economic growth generates a steady population increase and energy need, which is the reason for high levels of air pollution in the world today. Air pollution will continue to grow
at a rate quicker than overall economy, unless countries join together across the world to establish the same emission standards.
APPENDIX

Appendix A: Is an illustration from the Exxon Mobil 2013 Outlook for Energy, A View to 2040 showing a comparison between the world population in 2010 and the projected 2040 world population

Appendix B: Is a bar graph showing cities with the worst outdoor pollution in India and China

Appendix C: Particulate matter comparison

Appendix D: Energy Consumption between 1970 and 2020
REFERENCES


[9] https://www.google.com/search?q=china%27s+current+population&oq=china%27s+current+population&aqs=cchrome..69i57j0l5.7853j0j8&sourceid=chrome&espv=210&ie=UTF-8


Images

Appendix A: Is an illustration from the Exxon Mobil 2013 Outlook for Energy, A View to 2040 showing a comparison between the world population in 2010 and the projected 2040 world population.
Appendix C: Particulate matter comparison; [http://www.hcdoes.org/airquality/monitoring/pm.htm#PM 10 & PM 2.5...Huh]
Appendix D: Energy Consumption between 1970 and 2020

Figure 1: Rapid increasing of energy demand. The total energy consumption has increased 7 times from 1970 to 2004.