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Nitrogen Dioxide, Carbon Monoxide, Natural and Anthropomorphic Effects, and Earth's Changing Climate

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Abstract

This study will both compare and contrast the characteristics and roles of two pollutants: nitrogen dioxide and carbon monoxide. It will begin by tracing each gas' negative contributions to the Earth's spheres, as well as relate any negative links that each plays concerning human activity, health, and interaction with the environment. It will include an in-depth analysis of what the proliferation of such toxic gases indicates about human production and causality, plus reflect on any current attempts being made to improve the effects of these pollutants on the environment. This examination will also inspect three NASA missions, *i.e.*, MOPITT/Terra, AIRS/Aqua, and OMI/Aura, the aim of which, among many other tasks, is to detect pollutants within the Earth's various spheres, as well as analyze weather anomalies, improve prediction methodology, and chronicle meteorological patterns for future study. It will also cover some of the goals, engineering breakthroughs, and in one case, the limitations, of these three satellite missions. Finally, it should be noted that in all stages of this discussion, the author's main aim will be to focus on the positives that need to be implemented in order to improve the current situations that both anthropogenic and natural disasters have created for the planet.

Keywords

Carbon Monoxide, Nitrogen Dioxide, Climate Change, Atmosphere, Greenhouse Gases

1. Introduction

Nitrogen dioxide and carbon monoxide are two noxious gases greatly affecting the planet on all levels. How to eliminate so many of the catastrophic issues ultimately caused by both pollutants, anthropogenically and naturally, is a conundrum with which scientists and environmentalists are still grappling. Three NASA missions, all designed to tackle some of these environmental concerns, are currently formulating answers. However, in evaluating the roles of both nitrogen dioxide and carbon monoxide pertaining to the Earth's current state, a discussion of the planet's climate, atmosphere, and ultimately, living inhabitants, has to be brought to the fore. In an attempt to find solutions, scientists are still evaluating how much of the planet's present situation is related to nitrogen dioxide and carbon monoxide emissions, as well as how often this problem is based on anthropogenic causes or natural ones. Relevant discussions and scientific studies must look to how humans and the planet are being affected, of course, as well as what is currently being done to amend the situation. Moreover, glimpses into the causality of the Earth's present state in the first place should prove highly relevant for any long-term solutions.

2. Nitrogen Oxides and Nitrogen Dioxides

Nitrogen oxides are a group of reactive gasses, and nitrogen dioxide is just one of those. All nitrogen oxides are classes of pollutants formed whenever fuel is burned at very high temperatures, causing a reaction to other chemicals in the air [1]. The production of nitrogen dioxide affects humans, animals, the environment, and even the climate on both local and global levels. Nitrogen dioxide gets into the air from the combustion of fossil fuels like coal, gas, and oil, as well as emissions from automobiles, combustion engines, power plants, and even from equipment like butane and kerosene heaters and stoves. It is formed through the oxidation of nitric oxide by these emissions, and for humans, air contaminated with nitrogen dioxide can become toxic, creating or exacerbating health conditions such as asthma, infections, and respiratory distress.

Nitrogen dioxide has a shorter lifespan than many other nitrogen oxides, but it still plays a major role in the formation of ground-level ozone in the atmosphere through a series of reactions with organic compounds. It is roughly three hundred times more potent, for example, than carbon dioxide, and it is therefore a major factor in depleting the ozone layer. Other negative effects from nitrogen dioxide include damaging plants and trees, making them more susceptible to disease and decline [2].

Whenever nitrogen dioxide is in the air, it also reacts to other pollutants in the presence of sunlight, and this creates even further damage to the environment. Moreover, when nitrogen dioxide interacts with water, oxygen, and other chemicals in Earth's atmosphere, it can then create acid rain, which further harms the planet's delicate ecosystems, such as those within the lithosphere and hydrosphere by contributing to the deposition of nitrogen in the soil and in water. Any resulting nitrate particles from the production of nitrogen dioxide can also create hazardous fog and clouds. Furthermore, nitrogen dioxide contributes to the nutrient pollution of coastal waters [3].

3. Carbon Monoxide

Carbon monoxide, another toxic gas, is odorless and tasteless, but unlike the reddish color of nitrogen dioxide, it is colorless. It is formed as a byproduct of the incomplete combustion of carbon-based fuels such as wood, coal, propane, and natural gas, but is basically released whenever something is burned. Not only does it arise from anthropogenic sources, it can also occur naturally, like from the photochemical oxidation of methane into the atmosphere [4]. Flora can emit carbon monoxide as a metabolic byproduct, for example, and photooxidation of organic matter in lakes, streams, rivers, and oceans, plus surface soils, can also result in the formation of carbon monoxide. Just like nitrogen dioxide, its greatest producers to outdoor air are industrial processes that involve combustion, *i.e.*, vehicles and machinery that burn fossil fuels, and these all contribute heavily to carbon monoxide pollution [5].

In the home, certain items like unvented kerosene, gas space heaters, stoves, sealed chimneys, and furnaces can all release carbon monoxide gas in confined spaces. The gas then presents extreme dangers to both humans and animals when released indoors in high amounts. If inhaled, carbon monoxide can create tissue damage, can reduce the amounts of oxygen transported to the bloodstream to critical organs like the heart and brain, and this can ultimately lead to unconsciousness and even death in humans and animals [6].

On the other hand, carbon monoxide is already produced endogenously in humans during the normal catabolism of hemoglobin. Anthropogenic carbon monoxide emissions, compared to that from natural sources, are nearly impossible for scientists to quantify, but the Environmental Protection Agency has estimated that most of the problem is the result of human activity, with biogenetic emissions contributing far less to this issue [7]. Moreover, analyses in the United States have concluded that at certain times of the year, like during the summer months when forest fires are more prevalent, that natural sources of carbon monoxide can actually outweigh anthropogenic effects, so both can actually pose serious problems [8].

High levels of carbon monoxide are not as likely to occur outdoors like nitrogen dioxide does, with the exclusion of natural disasters like volcanoes and wildfires. However, whenever carbon monoxide levels are elevated enough outdoors, it can create a heavy toll on the environment, especially since it affects the amount of greenhouse gases produced. Gases like carbon monoxide easily link to multiple climate change issues, and although carbon monoxide does not directly cause climate change, in large enough amounts, it can still affect both land and sea temperatures greatly, causing changes to entire ecosystems, and even creating extreme weather conditions that increase the frequency of severe storms. Plus, it can contribute to the formation of a tropospheric ozone, which then becomes a secondary air pollutant [9].

3.1. Emission Control and MOPITT

All these issues have contributed to human attempts to both monitor and control nitrogen oxide and carbon monoxide emissions. Before 1999, virtually nothing was known about the global distribution of carbon monoxide [10]. It was in that year that the Terra satellite was launched, carrying a sensor known by the acronym "MOPITT' or "Measurements of Pollution in the Troposphere". MOPITT was the first payload, space-based, scientific instrument designed to consistently measure levels of released carbon monoxide around the globe, and with a scanning width of 640 kilometers, MOPITT easily scans the entire planet's atmosphere every three days [11].

MOPITT was launched into Earth orbit by NASA, but was funded by the Canadian Space Agency, a little over two decades ago with the intent to monitor changes in pollution patterns and to study any effects on the lower atmosphere. It also utilizes spectroscopy to gage profiles of carbon monoxide in various areas there. Plus, it allows scientists to see the distribution, transport, sources, and areas of carbon monoxide. Although launched in December 1999, it was not operational until the year 2000. Terra has been in orbit long enough to observe multiple changes over the last two decades.

MOPITT displays geographic variabilities and seasonal variances of carbon monoxide distribution. It gives scientists a monthly map pertaining to carbon monoxide, since the pollutant can last for roughly one month in the Earth's troposphere. Unfortunately, that is just enough time for it to be transported to other areas of the planet through wind. Thankfully, this amount of time is not long enough to distribute the toxic gas all over the Earth's atmosphere [12].

3.2. Wildfires, Pollution, and MOPITT

Fires are a main source of carbon monoxide pollution all over the planet, and there are several locations throughout the Earth where MOPITT's monitoring maps have been useful. In Africa, for example, purposeful and un-purposeful burning of agricultural land and crops shifts carbon monoxide both north and south of the equator concurrent with the seasons, causing seasonal shifts in the gas' distribution. In another case, MOPITT has been particularly useful with the fairly recent outbreak of wildfires in both Australia and the United States. MOPITT has also shown how badly urban areas throughout the world are affected by carbon monoxide gas from both vehicles and industrial emissions.

In all fairness, MOPITT's mapping system has shown that many concentrations of carbon monoxide have actually declined since its Terra satellite was initially launched, and that this decline is especially noticeable in the Northern Hemisphere of the planet, where technological and regulatory innovations seem to be making more of a difference overall there than elsewhere. Also, according to MOPITT, the Earth's Southern Hemisphere is still showing improvement, indicating decreases in deforestation fires. However, although MOPITT observed some decreases in carbon monoxide over various areas, other satellites have shown that other toxic pollutants, like nitrogen dioxide, have now increased and become far worse over the last two decades.

3.3. MOPITT and NASA's Terra Mission

MOPITT has also shown that in evaluating and monitoring localized carbon monoxide values, especially in urban locations, that it can often be influenced by things like topography, vegetation, infrastructure, and even meteorological factors. Unreacted carbon monoxide in the troposphere can be slowly transported to the mesosphere and stratosphere, where it then reacts with atomic oxygen brought on by the photo dissociation of oxygen. MOPITT mappings have even shown how the planet's oceans may become saturated with carbon monoxide and are actually a net source of atmospheric carbon monoxide. However, although oceans have been shown to be a net source of the gas within the environment, scientists have also discovered that various microorganisms degrade carbon monoxide in water at the same time.

The Terra mission has significantly helped reveal important information about carbon monoxide levels and human activity, as well as how it has affected the entire biosphere. It must be noted that despite the fact that humans live within the troposphere, monitoring the tropospheric composition from space has been far less explored than the upper areas of the atmosphere due to a lack of significant technology. The planet's surface serves as a hindrance to many measuring technologies and the presence of fog and clouds can further debilitate this. The mission has successfully collected valuable data though, allowing scientists to better understand how the troposphere has reacted to stimuli such as deforestation, as well as the growth of new vegetation.

As a resource, the Terra mission has served humanity far more than as just a satellite that measures climatic variables, it has also been useful to detect carbon monoxide levels in areas where collection of ground measurements in extreme environments is next to impossible, like in the North and South Poles, for example, or situations where there is civil unrest among peoples or in extremely remote areas of the globe. It has also provided crucial data for agriculture and the food humans need to survive, as well as the catastrophic events humans are causing such as biomass burnings. All in all, studying carbon monoxide is important since it displays how chemicals are transported to the troposphere where humans dwell, as well as provides valuable information about any chemical reactions it can cause. Moreover, any changes to this delicate system can easily affect the overall climate system for the planet [13].

4. Atmospheric Infrared Sounder

Launched by NASA in the spring of 2002, AIRS, or the Atmospheric Infrared Sounder, on board the Aqua satellite, garners data on the infrared energy coming from the planet's surface and atmosphere each day. AIRS' main mission is to support climate research, improve weather forecasting, and to provide critical information monitoring the planet's atmosphere. It also utilizes infrared technology to create 3D measurements, determining temperature, cloud properties, and water vapor within the atmosphere, as well as produces measurements pertaining to trace gases, as well as topographical and cloud properties. It is the most advanced atmospheric sounding system ever sent into space, and it also observes and monitors the global water and energy cycles, climate anomalies, as well as the climate's response to greenhouse gases [14].

The Aqua satellite is one of a series of sun-synchronous satellited stationed in low Earth orbit and its main goal is to observe all the spheres of the Earth (biosphere, lithosphere, hydrosphere, and the lithosphere). NASA has estimated that AIRS is the equivalent to launching 300,000 weather balloons over a 50 km radius over the Earth each day. Moreover, the launch of AIRS has proven extremely relevant and important to humans, since it provides immediate and fast global coverage of several areas of concern within the biosphere. For the most part though, AIRS provides information and imaging over land masses and oceans unobtainable in several remote locations here on earth [15].

4.1. Toxic Gases, Greenhouse Gases, and AIRS

AIRS provides vital information about toxic gases affecting the atmosphere and measures trace greenhouse gases such as carbon monoxide. It is also the most advanced water vapor sensor ever constructed, and it continues to improve existing climate models. It also logs historical information about the atmosphere for generations to come. Such a fingerprint can be used to predict and monitor future causes and locations of the release of carbon monoxide, serving as a type of greenhouse gas sensor. Since water vapor is the most prolific greenhouse gas in the planet's atmosphere, and accounts for roughly 60% of the greenhouse effects to the atmosphere, it therefore can exceed the harmful effects of carbon monoxide.

4.2. AIRS Instrumentation

It is notable to point out that the term "sounder" in the "AIRS" acronym refers to the instrument measuring the temperature and water vapor as a function of height, something known as "atmospheric sounding." Also, a sort of scan mirror rotates on an axis along the craft's flight path, directing infrared energy from the planet to the instrument. Within the instrument itself there is an advanced, high-resolution spectrometer, separating the infrared energy into wavelengths. Infrared wavelengths are very sensitive to temperature and water vapor over varying ranges of height and depth within the atmosphere, and this goes all the way up into the stratosphere. Each infrared detector senses particular wavelengths, temperature profiles, or sounds, and for the first time ever, the microwave instruments on board Aqua are of the type that can see though clouds with excellent accuracy [16].

Computer algorithms and microwave instruments from AIRS are also combined to provide excellent measurements of the current state of all areas of Earth's atmosphere. AIRS' instruments are able to measure the infrared brightness that is ejected from both the planet's surface and atmosphere. In gathering infrared energy emitted from Earth's surface and atmosphere, weather forecasting for humans is vastly improved. It even predicts some of the natural events affecting humans. For example, volcanic plumes can be better detected, as well as drought prediction. Moreover, the infrared spectrum provided by AIRS is a wellspring of information pertaining to carbon monoxide within Earth's atmosphere.

AIRS can improve forecasts, so that the locations and magnitudes of life-threatening storms can be better predicted for humans. It can even detect carbon monoxide emissions from burning vegetation and animal waste humans have created in both remote and urban areas. It can follow gas plumes from large area burns, enabling scientists to watch the transportation patterns of carbon monoxide, and it can even show how ozone is transported, giving scientists an excellent detection of atmospheric ozone in Polar Regions during the winter, as well as identify large concentrations of dust that could create hazardous issues for humans [17].

4.3. Ozone Monitoring Instrument

Another monitoring system from NASA is the Ozone Monitoring Instrument, or OMI, which is an ultraviolet spectrometer included on the Aura spacecraft. Aura flies behind Aqua, and both orbit in a polar, Sun-synchronous pattern, the former flying an estimated 15 minutes behind the latter. Launched in the summer of 2004, OMI's task is to interpret aerosol types, like smoke, dust, and sulfates, and it also measures cloud pressure and coverage, providing data on the tropospheric ozone for humans [18]. OMI records the total ozone and other atmospheric parameters related to both chemistry and climate. However, Aura is basically NASA's chemistry mission, monitoring both the chemistry and dynamics of Earth's atmosphere, from the lithosphere to the mesosphere. Its main objective is to monitor the interactions between atmospheric constituents from natural sources, like volcanoes, as well as anthropomorphic ones, such as biomass burning, that are contributing to climate change, as well as depleting the ozone [19].

OMI can measure much larger amounts of atmospheric constituents and thus provides some better ground resolutions for scientists. It closely monitors the recovery of the ozone layer in response to the phase out of chemicals harmful to humans, and it measures pollutants such as nitrogen dioxide. Since nitrogen dioxide can pose a human health risk and reduces agricultural productivity, the OMI helps significantly by tracking both industrial pollution as well as the biomass burning causing carbon monoxide. Furthermore, these all play important roles in the chemistry make-up of the Earth's stratosphere and troposphere, and emissions from both man-made and volcanic activity significantly impacts the air quality of humans and animals, as well as the climate, and this is now being better monitored through OMI.

OMI also detects carbon monoxide formations due to ash from volcanic eruptions, and this is not just relevant to human health, but also aircraft safety and aircraft visibility. It also provides global surveys of nitrogen dioxide and carbon monoxide, relating them to temperature, geopotential heights, and aerosol fields. But unlike some of the other NASA missions, OMI mainly focuses on the lower stratosphere and the troposphere, rather than the other atmospheric areas [20].

Lastly, it should be noted here that shortly after launch, a problem was detected with this specific mission. A piece of plastic was dislodged during the explosive outgassing of the craft during its ascent, and that issue is now blocking about 80% of the optical instrument aperture. Unfortunately, the plastic piece has remained on the scan mirror despite numerous attempts to remove it. As a result, the ground team is only using about 20% of the aperture to obtain data, and worse, the instrument does not have scanning capability, which further hinders the information received at ground stations [21].

5. Findings Summary

In summary, by measuring the pollutants carbon monoxide and nitrogen dioxide, scientists can enhance their knowledge of what is happening within the various levels of Earth's atmosphere, as well as the planet's biosphere, lithosphere, and hydrosphere. Monitoring the release of these toxic gases, which is expelled from vehicles, fires, and through industrial methods, affects the atmosphere's natural potential to eliminate harmful pollutants. In monitoring the concentrations of both nitrogen dioxide and carbon monoxide, scientists are now better able to locate and then track harmful gases back to their sources, thus finding ways to improve the lives of humans and animals, as well as improve agricultural methods, predict harmful weather patterns, better predict natural disasters, and find solutions for climate changes that are further impeding efforts to improve the contagion of harmful effects on the planet. Furthermore, in providing data on the current state of the atmosphere, hydrosphere, lithosphere, and cryosphere, as well as the interactions with solar radiation, NASA missions, like the ones outlined in this study, are providing crucial topological information. The continuous measurements produced by these three missions, which monitor vulnerable areas of the planet, studies wildfires, agricultural burning, the burning of waste materials from industries and biofuels, plus provide important information as to the distribution of smoke-plumes, regional meteorology, climate, ecosystems, and human health-related concerns, has proven invaluable on many levels. In short, these satellites have been key in identifying pollutants like nitrogen dioxide and carbon monoxide and have better shown the effects these have on humans, as well as planetary activity in every corner of the globe. Remotely sensing and viewing from space has revealed the main culprits behind the major causes and contributors of multiple environmental issues on the planet.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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