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Impact of the COVID-19 pandemic on the emissions of some atmospheric gases and global warming

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ABSTRACT

COVID-19 and its variants have become a nightmare. The COVID-19 pandemic has affected every aspect of human life. Therefore, this study will investigate the impact of the COVID-19 pandemic on the emissions of carbon dioxide (CO_2) and nitrogen dioxide (NO_2) gases, and their effect on global warming. Data are collected by international research laboratories and organizations, such as Mauna Loa Observatory in Hawaii. Samples from four 7-m towers and one 27-m tower have air intakes at the top from which Mauna Loa continuously collects air samples. Each hour, four air samples are taken in order to calculate the CO_2 content. The observed tropospheric NO_2 column concentration data were collected from satellite and surface air quality data from ground monitoring. The results indicated that global CO_2 emissions decreased by 8.8% in the first six months of 2020 compared to the same period in 2019. The mean NO_2 concentration throughout the Northern Hemisphere was 64 µmol m^{-2} in 2019, but in 2020 it dropped to 52 µmol m^{-2}, a 19% decline. The UN report indicates that the global temperature has risen 1.5°C above the pre-industrial degree. It is a mandatory issue to reduce global warming and environmental pollution by reducing the emissions of gases, such as CO_2 and NO_2. The emissions must be reduced by 45% by 2030 and reach a degree of zero emissions in the industrial and transportation sectors by 2050.

Keywords: COVID-19 pandemic, environment, CO_2 emission, NO_2 emission, climate change.

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INTRODUCTION

We are in the era of COVID-19, and the world has changed drastically. It is stated that the world before COVID-19 will never be the same as it was after COVID-19. People's health has been greatly affected by the COVID-19 lockdown not only physically but also mentally and psychologically. The COVID-19 pandemic has posed an extraordinary challenge to people's health, food systems and global business systems. The pandemic has brought about decisive economic and social change. It is estimated that ten million people are at risk of falling into extreme poverty, and about 690 million people are undernourished and lack of food; this number could rise to 132 million people by the end of 2020 (ILO et al., 2020). Many companies have gone bankrupt and others face an existential threat. As estimated, the world's labor force is around 3.3 billion, and about half of the workforce is at risk of losing their livelihoods.

As stated in the World Health Organization (WHO) report "We must rethink the future of our environment and tackle climate change and environmental degradation with ambition and urgency. Only then can we protect the health, livelihoods, food security and nutrition of all people, and ensure that our 'new normal' is a better one" (ILO et al., 2020).

Carbon dioxide is one of the greenhouse gases, and it has a significant impact on global warming. Carbon dioxide emissions into the atmosphere are expected to decrease due to the COVID-19 pandemic. As we can see around the world, the transportation sector has been greatly affected, especially aviation since the emergence of COVID-19 on December 30, 2019, in China. It was declared a global pandemic by the WHO on March 11, 2020. Energy demand patterns have changed dramatically due to COVID-19 (Le Quéré et al., 2020).

People's freedom of movement was constrained, and international borders were blocked. These governmental decisions have had an impact on energy use and have significantly changed global patterns of energy demand.

The emission of carbon dioxide had increased before COVID-19 by about 1% over the previous decade (Friedlingstein et al., 2019; Jackson et al., 2019; Peters et al., 2020). It is mentioned that “Presenting the latest data on emissions, global temperatures and climate impacts on Earth's oceans and frozen regions, the report showed the atmospheric concentration of CO_2 hit 414.38 parts per million in July 2020, compared with 411.74 ppm a year earlier (Mauna Loa Observatory, 2019; World Economic Forum, 2020).

NO_2 is one of the important gases, it has reddish brown color and is toxic, and it is one of the atmospheric pollutants. It is a common pollutant and is considered to be a precursor to the formation of ozone and fine particulate matter (Liu et al, 2022). NO_2 is released into the environment due to industry and moving automobiles on the road. It is regarded as a reliable indicator of the world economy. NO_2 impacts human health by increasing asthma cases, affecting the respiratory system, affecting human death, and causing lung cancer (Pannullo et al., 2017; Tao et al., 2014; Zeng et al., 2020; Anenberg et al., 2018; Achakulwisut et al., 2019; Hamra et al., 2015; Brook et al., 2007; Crouse et al., 2015). Nitrogen oxides (NOx) are released globally to the atmosphere on an annual basis of around 50 Tg; this amount is divided between natural resources, about 23%, burning of fossil fuels (in traffic, power plants, industry, etc.), 58%, and the remaining 19% come from burning biomass (Dentener et al., 2006).

The emission of CO_2 and NO_2 affects the climate by increasing temperature and increasing air pollution. The COVID-19 pandemic is a great opportunity to reduce emissions. For example, the transportation sector, especially aviation, can be one of the factors to reduce emissions by reducing the number of flights. There is a global trend that the world needs to reach zero emissions, but this trend may be dangerous, especially for carbon dioxide emissions. The emissions of CO_2 must be controlled so they do not exceed the safe level in the atmosphere. There won't be any photosynthesis if CO_2 emissions are zero. Since photosynthesis is a crucial activity that cannot occur in the absence of CO_2, life on Earth will also come to an end. This study aims to show the effect of COVID-19 pandemics on CO_2 and NO_2 emissions, and the effect on climate change during the lockdown.

RESEARCH METHODOLOGY

The data for this study about the impact of the COVID-19 pandemic on atmospheric CO_2 and NO_2 concentrations were collected from international research laboratories, such as Mauna Loa Observatory in Hawaii, the United States National Oceanic and Atmospheric Administration (NOAA), and arxiv.org. According to Mona Loa Observatory, samples from four 7-m towers and one 27-m tower have air intakes at the top from which Mauna Loa continuously collects air samples. Each hour, four air samples are taken in order to calculate the CO_2 content. A Siemens Ultramat 3 nondispersive infrared gas analyzer with a water vapour freeze trap is used to measure CO_2. The working reference gas is used during measurements. The present CO_2-in-air calibration gases were introduced in December 1983 to replace the CO_2-in-N_2 calibration gases. Periodically, the sensitivity of the device and the presence of any potential contamination in the air-handling system are checked by comparing these calibration gases with other reference gases. These standard gases, whose CO_2 contents are measured manometrically, serve as the reference gases for the calibration of the reference gases themselves (Mona Loa Observatory). Keeling et al. (1982) and Keeling et al. (2002) provide more information regarding the sampling techniques used at Mauna Loa. In Bacastow et al. (1985) more information regarding the Mauna Loa data selection process is provided. The reports and researches about the effects of the COVID-19 pandemic will be analyzed. Analysis and interpretation of the data will be done using scientific logic procedures.

RESULTS AND DISCUSSION

Situation of CO_2 emission

There is a daily record for the amount of CO_2 in the atmosphere; for instance, on January 31, 2021, it was 416.19 ppm and on January 31, 2022, it was 419.41 ppm (Mauna Loa Observatory, 2019) (Figure 1). If we compare the values for the two years, 2021 and 2022, we can see that the CO_2 emission in the atmosphere decreases in January 2021 but then increases in January 2022. The percentage of CO_2 increases by about 0.8 % in 2022. This means that the activities have increased in 2022 after releasing most of the pandemic restrictions globally. This also reflects the improvement of international communication although COVID-19 and its variants are still ongoing. As estimated in the first six months of 2020, the emission of CO_2 decreased by 8.8% (1551 Mt CO_2) globally compared to the same period in 2019 (Liu et al., 2022). As stated, “The magnitude of this decrease is larger than during previous economic downturns or World War II”. The most affected sectors are transportation, power and industry, their emission of CO_2 account for 86% of the total reduction in emissions of the whole world. CO_2 emissions declined by –60% or –1.7 (–1.3 to –2.2) $MtCO_2\,d^{-1}$ in the aviation sector, which yielded the largest relative anomaly of any sector, and by –21% or –0.9 (–0.3 to –1.4) $MtCO_2\,d^{-1}$ in the public

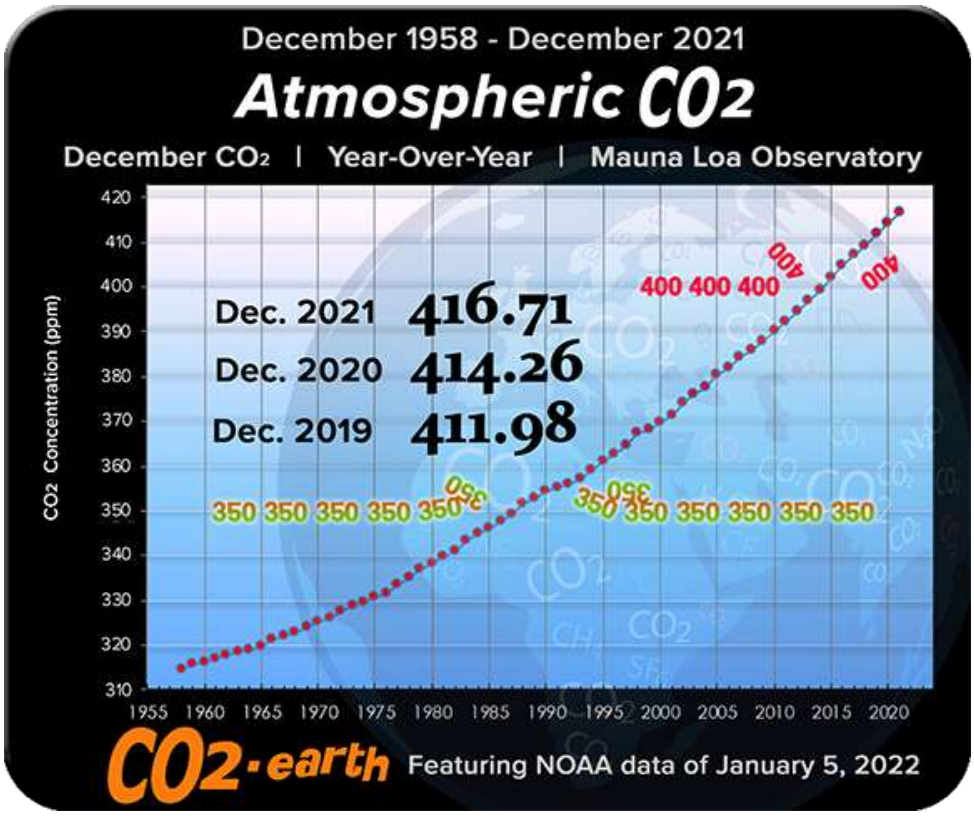

Figure 1. CO_2 concentration in the atmosphere from Dec. 1955 till Dec. 2021 (Mauna Loa Observatory, 2019).

sector. The daily emission of CO_2 has been recorded. It was reported that mean daily emissions from January to June 2020 were 88.4 Mt CO_2 per day, which is 10% lower than the daily average emissions during the same period in 2019 (98.2 Mt CO_2 per day (Liu et al., 2022). The impressive and interesting study by Liu et al. covers 57 countries and 416 cities worldwide refer that there is a significant decrease in CO_2 emission during the COVID-19 lockdown (Liu et al., 2022). The study covers some sectors, such as ground transportation, industry and cement production, power generation, aviation and shipping, and commercial and residential buildings. The emission of CO_2 has decreased in all sectors due to the COVID-19 pandemic. The activities are increased in many countries after relaxing the pandemic restrictions. Figure 2 shows the record of CO_2 emission globally in 2020 and 2021 (Liu et al., 2022). The results of Figure 2 showed that the emission was 96.28 Mt CO_2 on January 1, 2020, but the amount increased to 100.27 Mt CO_2 on January 1, 2021. This result refers that the activities have increased due to easing COVID-19 restrictions in many countries. As expected, the emission of CO_2 decreased to 78.81 Mt CO_2 on June 1, 2020, and 88.28 Mt CO_2 in June 2021. June 2020 was the peak of the COVID-19 pandemic, therefore, the activities decreased, and this led to a decrease in CO_2 emission. The emission reduction is about 18%, which means that the activities that include carbon, such as burning fossil fuels, are reduced during the pandemic period. The emission of CO_2 has decreased by about 12% in June 2021. If we compare both percentages, 18% in June 2020 and 12% in June 2021, it can be seen that the COVID-19 pandemic restrictions have been relaxed in 2021, and this measure leads to an increase in CO_2 emissions. The maximum emission was 108.05 MtCO_2 on January 8, 2020, and 116.52 Mt CO_2 on January 8, 2021. The minimum emission was 68.65 Mt CO_2 on May 3, 2020, and 79,07 Mt CO_2 on May 2, 2021 (Liu et al., 2022). The maximum value of CO_2 emission indicates that the activities increase globally in January 2020 and 2021. Although the COVID-19 pandemic is still ongoing in many countries, there is an indication of relaxing the pandemic restrictions globally. The lowest CO_2 emissions are unusually occurring in May. This might be because the COVID-19 pandemic restrictions have increased. The greatest quantities of carbon dioxide ever measured in the atmosphere have been revealed by climate scientists. The planet has reached a new milestone of 50% greater than pre-industrial levels, a concentration not seen in over 4 million years, in the latest in a long run of record-breaking years (Irving, 2022). The most recent measurements made by the Mauna Loa Atmospheric

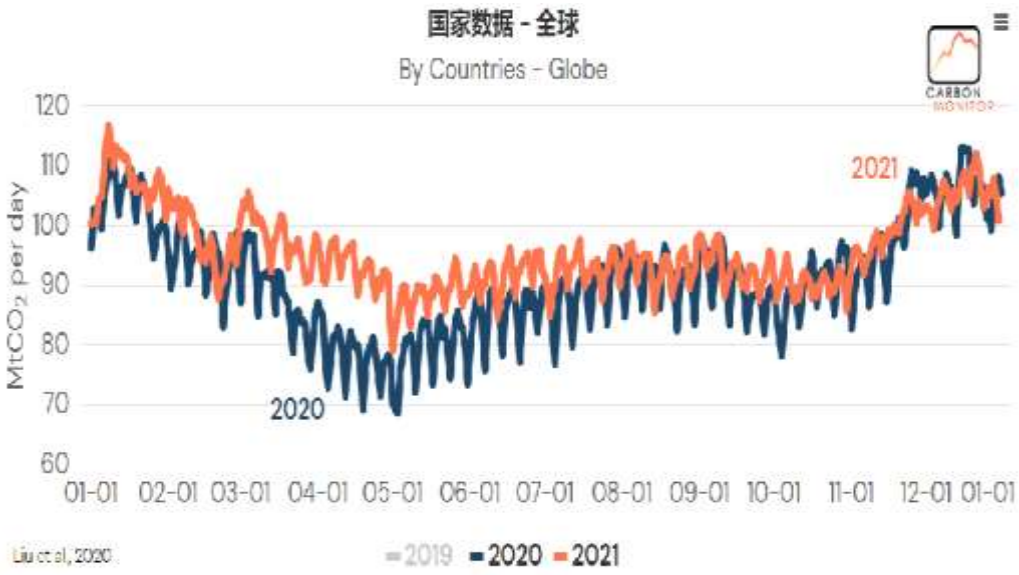

Figure 2. The variation of CO_2 emission globally in 2020 and 2021 (Liu et al., 2022).

Baseline Observatory in Hawaii indicated that CO_2 in the atmosphere was 420.99 ppm in May 2022. The value of CO_2 recorded in May 2021 was 419.13 ppm, this means that the concentration of CO_2 in the atmosphere has increased by 0.44%. This percentage means that millions of tons of CO_2 are added to the atmosphere. Also, the value of CO_2 recorded in May 2020 was 416.21 ppm. If we compare the value of CO_2 in May 2022 and in May 2020, it can be seen that the CO_2 level in the atmosphere has increased by about 1.14 %. Accordingly, millions of tons of CO_2 have been emitted into the atmosphere. Generally, the safe level of CO_2 in the atmosphere should not be more than 350 ppm. Currently, the level exceeds the safe level of CO_2 by about 17%. This implies that as long as the rate of CO_2 emissions keeps rising, so will the temperature of the atmosphere. The International Energy Agency (IEA) estimated that worldwide CO_2 emissions decreased by about 5% between January and April 2020 compared to the corresponding period in 2019 using monthly predictions of the demand for fossil fuel energy (IEA, 2020).

Situation of NO_2 emission

During the COVID-19 lockdown, a study was conducted on NO_2 levels in China and Italy (Gosh, 2020). According to reports, NO_2 levels in China have fallen throughout the shutdown, particularly in January and February 2020. Due to increased activities and the lifting of lockdowns, the level begins to rise again in March 2020. Italy is a major industrial country in Europe, with the industrial sector accounting for roughly 24% of the GDP. As a result, the lockdown had a substantial impact on business operations. Accordingly, the emission of NO_2 has decreased in Italy. It is reported that data from satellites show a decrease in tropospheric NO_2 column concentration (Krotkov et al., 2017; van Geffen et al., 2020). Additionally, NO_2 concentrations in the atmosphere are declining, according to air quality stations. The most recent study about NO_2 emissions indicates that its emissions have decreased during the COVID-19 pandemic (Cooper et al., 2022). The study covers 200 cities worldwide and reveals that “Mean country-level population-weighted NO_2 concentrations are 29 ± 3% lower in countries with strict lockdown conditions than in those without”. It is estimated that a 50% reduction in anthropogenic NO_x emissions resulted in a 5% change in the monthly average weighted NO_2 concentrations for populations in North America, Europe and Asia for March 2020 (Cooper et al., 2022). As reported in 2020, the number of daily vehicles in New York City decreased from about 749,761 in February to 537,147 in March and to 280,324 in April, this was because of the COVID-19 pandemic (Bar et al., 2021). The variations of NO_2 concentrations in the atmosphere are not only attributed to variations in transportation and industrial activities but also it is attributed to changes in weather (Collivignarelli et al., 2021; Wong et al., 2021). A study was done to describe the variation in tropospheric NO_2 concentration between 2019 and 2020 (March-May), respectively, a relative percentage deviation (RPD) was developed by using equation 1, where Xc and Xp are the mean NO_2 (March to May) in 2020 and 2019, respectively (Bar et al., 2021). In order to find any anomalies brought on by the COVID-19 pandemic, mean NO_2 and RPD data were analysed both globally and in 11 major cities where lockdown restrictions were in place (such as Paris, Milan, Madrid, New York, Boston, and Springfield), where they were partially or completely not enforced (e.g. Stockholm,

Warsaw, Bismarck, Pierre, Lincoln). The data made within a 20 km radius of the city centre were combined in the analysis that was done over the urban areas. The RPD for NO_2 at the ground-based station. Equation 1 was likewise used to calculate the 5 levels, but the Xp is the long-term mean for the years 2015 to 2019. According to an analysis of the mean NO_2 concentration's global variance in 2019, the mean NO_2 concentration over the Northern Hemisphere was 64 μmol m^{-2}, but it decreased by 19%, which represented 52 μmol m^{-2} in 2020. High population density and industrial activity could affect the concentration of NO_2. Therefore, the highest concentrations of NO_2 are recorded in Asia, particularly eastern China, where concentrations reach 300 μmol m^{-2} in 2019. India, Europe, and the eastern United States had the greatest NO_2 concentrations, with average NO_2 levels in 2019 of 230, 219, and 255 μmol m^{-2}, respectively (Bar et al., 2021).

$$\text{RPD} = \frac{Xc - Xp}{Xp} \times 100 \quad (1)$$

COVID-19 and global warming

There is no doubt that the climate has been affected due to the change in CO_2 and NO_2 emissions. CO_2 is one of the greenhouse gases, and it is the most important greenhouse gas. The United Nations (UN) issued a report prepared by the United Nations' top climate scientists, and the report notes that global warming continues unabated, and shows the great danger and dire consequences for entire countries of the world. The UN describes the situation of global warming as a "criminal" act. (Cooper, 2022). This report sounds the alarm about global warming, especially the increase in natural disasters, such as floods and hurricanes, and global warming, as we can see heat waves in summer. Also, the melting of the ice caps of the poles and permafrost in the Arctic is accelerating. According to the report, the average global temperature has increased by 1.5°C since pre-industrial times. It is noteworthy that the average temperature for the entire planet in February 2022 is 1.19°C (Mauna Loa Observatory, 2019). This is the 5th warmest February since 1880. The global temperature in 2021 is +1.12°C, which is the 6th warmest year since 1880. By comparing the two values, it can be seen that there is an increase in global temperature of about 6% in just two months from 2022. The most important and dire conclusion of the report is that "Its findings show that the world faces unavoidable climate hazards over the next two decades, with the populations and ecosystems least equipped to cope being the hardest hit." The main goal that must be achieved is to limit the rise in global temperatures to 1.5°C. Therefore, it is stated that to achieve this goal, the world needs to reduce emissions by 45% by 2030 and reach a degree of zero emissions by 2050. "The correlation between atmospheric CO_2 levels and global average temperature shows an increase in global temperature. This is because of increasing CO_2 levels in the atmosphere, as shown in Figure 3. Solar energy has no effect on global temperature (Cooper, 2022; Etheridge et al., 1996).

"This report is a dire warning about the consequences of inaction," said Hoesung Lee, Chair of the Intergovernmental Panel on Climate Change (IPCC) "It shows that climate change is a grave and mounting threat to our well-being and a healthy planet. Our actions today will shape how people adapt and nature responds to increasing climate risks"(Lavars, 2022). UN secretary general, António Guterres, said "The facts are undeniable. This abdication of leadership is criminal. The world's biggest polluters are guilty of arson of our only home." There is a study that contains the data for 206 nations (C3S, 2017), accounting for the weekly cycles and holidays that vary by nation. According to the unusually warm winter in the northern hemisphere ((ECMRWF, 2020), the demand for heating fell globally in the first seven months of 2020 by 2.1% compared to 2019. This decline in demand led to a corresponding decline in emissions from this industry. According to the NOAA report, "Increasing concentrations of greenhouse gases in Earth's atmosphere represent a long-term commitment by society to living in a changing climate and, ultimately, a warmer world (PCC, 2014, Working Group I)". As reported by ICPP group, the problem is that "climate change has disruptive and uncertain consequences for agriculture, water supply, transportation, coastal communities, the economy, energy, ecosystems, and national security (IPCC, 2014, Working Group II)". The variation in GHG emissions up to 2020 has been recorded by NOAA, as shown in Figure 4. As presented in the figure, the emissions of CO2, N2O, and CH4 increased during the COVID-19 pandemic, but the emission of CFC decreases during the pandemic (AGGI, NOAA, 2022). This might be due to some heavy industries being stopped during the COVID-19 pandemic lockdown.

In Sharm El-Sheikh, Egypt, from November 6 to 18, 2022, the 27th Conference of the United Nations Framework Convention on Climate Change (COP27) was held. The COP27 aimed at implementing climate action, including the 2015 Paris Agreement. World leaders, scientists, activists, and negotiators attended COP27. In order to achieve the Paris Agreement's target of keeping global warming to "well below" two degrees Celsius, ideally 1.5°C, current pledges to reduce emissions fall well short of what is required. According to current promises, the global temperature rise by the end of the century would be between 2.4 and 2.6°C higher than preindustrial levels, according to a recent UNEP research. Unfortunately, the pledges are not fulfilled, and the global temperature is currently about 2.8°C. This means that emissions of gases are greater than the required limit and the pledges of the world leaders are not fulfilled (Thompson, 2022).

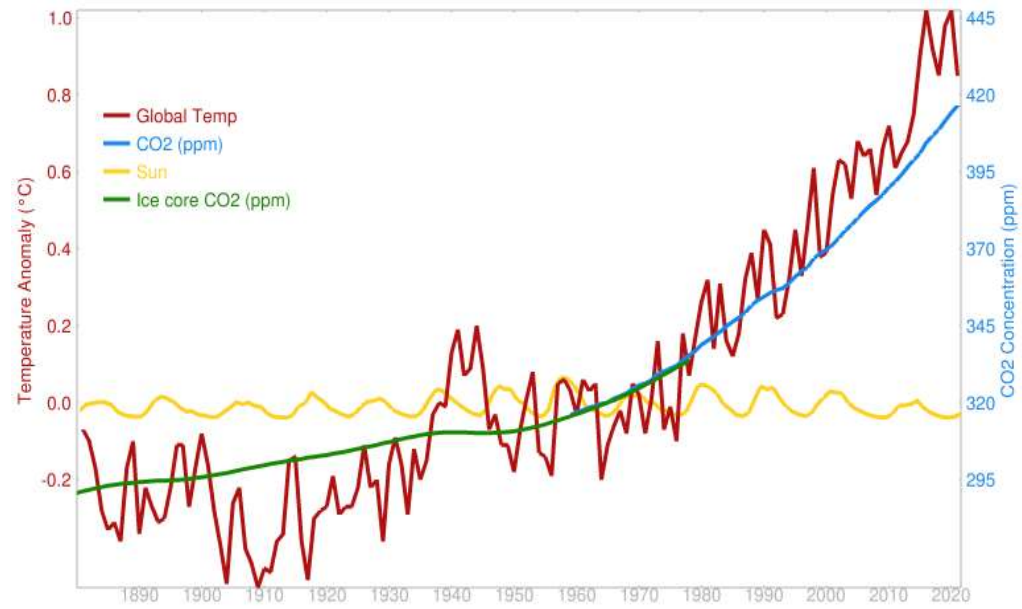

Figure 3. Effect of atmospheric CO_2 and solar energy on global temperature since 1880 (Cooper, 2022; Etheridge et al., 1996).

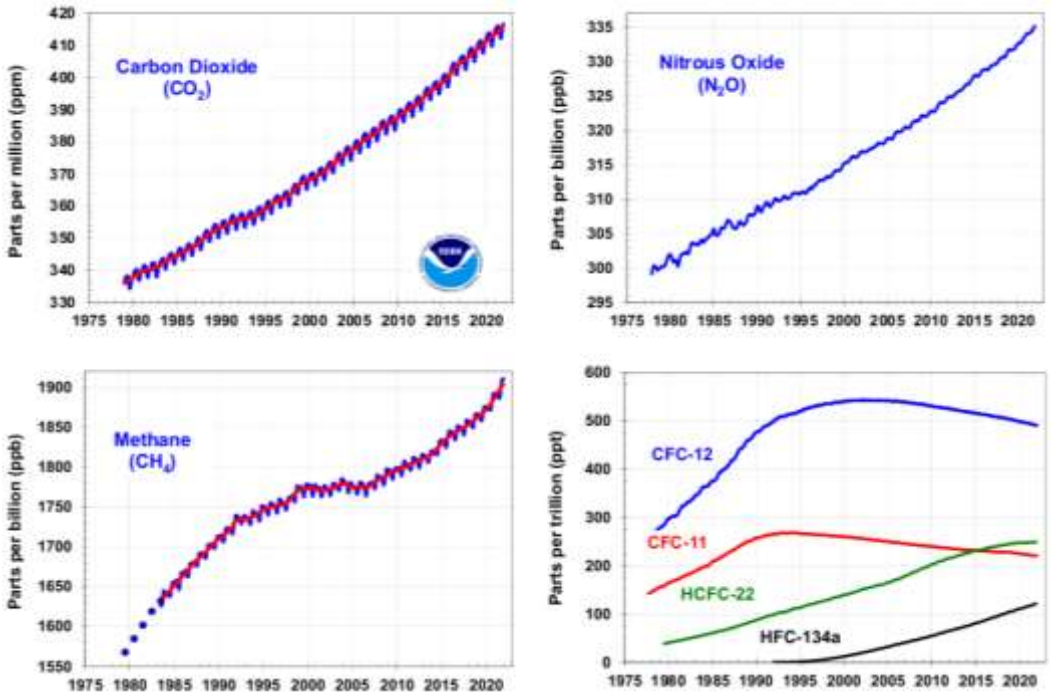

Figure 4. GHG emissions as reported in the NOAA Annual Greenhouse Gas Index (AGGI).

CONCLUSION

The COVID-19 pandemic has had a significant impact on CO_2 and NO_2 emissions, and it has caused the closure of various industrial sectors, particularly the transportation sector. Some studies reported that the emissions of CO_2 decreased by 8.8% in the first 6 months of 2020. Some studies revealed that in comparison to 2019, the demand for heating decreased by 2.1% globally in the first seven months of 2020. As reported, air quality stations recorded

a decrease in NO_2 concentrations in the atmosphere during the COVID-19 pandemic. The UN report indicates that the global temperature has risen 1.5°C above the pre-industrial degree. There is a need to limit the rise in global temperature to 1.5°C. Paris agreement has not been implemented. The current situation of global temperatures can be considered very high. According to climate change reports, the current global temperature moves towards 2.8°C. Therefore, the world needs to reduce emissions by 45% by 2030 and reach a degree of zero emissions in sectors, such as transportation and industry by 2050.

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