The effect of human activities on Bali's Silent Day (Nyepi) in 2022

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Abstract. During Nyepi, all activities are eliminated, including public services, such as closing access to land, sea, and air transportation routes that transit to Bali for one day. In 2022, the BMKG Research and Development Center observed air quality in Nyepi. The measurement aims to determine the relative reduction level of greenhouse gas (GHG) and particulate emissions on Nyepi Day compared to before and after. Greenhouse gases and particulates were measured for seven days, February 28 - March 6, 2022. The measurement locations were over 3 points: Denpasar Regional Office III, Karangasem Geophysics Post, and Jembrana Climatology Station. The results of this field measurement show that daily human activities significantly influence the concentration of pollutant gases and particulates in the air. During Nyepi Day, air concentration improves when all human actions are reduced. This is marked by a decrease in the air's concentration of pollutant gases (CO, NO2) and dust particles. The reduction in the concentration of pollutant gases and dust particles did vary at each observation location; this was due to the sensitivity of the equipment, the character of each observation location, and the placement of measuring devices. Urban areas filled with community activities have experienced the greatest improvement in air quality compared to suburban areas. Order of measuring instruments close to the location of pollutant sources, even in suburban areas, will decrease the concentration of pollutant gases, similar to that in urban areas. The difference between PM25 data during Nyepi 2022 and the average PM25 for 2020 - 2022 shows a decrease in PM25 concentrations of around 47%, with the highest drop at night.

1 Introduction

Nyepi, the annual Balinese "Day of Silence," represents a unique cultural and religious event observed on the Indonesian island of Bali. This day is characterized by a complete cessation of all activities, including the closure of public services and the suspension of land, sea, and air transportation routes to and from the island. The Nyepi rituals are performed with no fire, no light, and no electricity (amati geni), no working (amati karya), no travel (amati lelunganan), and no revelry or self-entertainment (amati lelanguan). The Balinese community

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collectively participates in this day of introspection, meditation, and fostering a peaceful environment, during which silence and self-contemplation are paramount. Beyond its profound cultural and spiritual significance, Nyepi provides an invaluable opportunity to investigate the environmental impact of human activities on air quality. In 2022, the Research and Development Center of the Indonesian Agency for Meteorology Climatology and Geophysics (BMKG) conducted a comprehensive study aimed at assessing the changes in air quality and pollutant levels during Nyepi, with a particular focus on evaluating the reduction in greenhouse gas (GHG) and particulate emissions.

This research holds significance in the broader context of environmental science and air quality management. The growing significance of human activities on air quality is gaining attention because of its implications for public health and the environment. Academic studies have shown that air pollution, often resulting from the emission of GHGs and particulates, can harm respiratory health, cardiovascular health, and overall well-being [1,2]. Furthermore, it is well-established that reducing human activities, such as industrial and vehicular emissions, can improve air quality, which can, in turn, positively affect public health and ecosystem sustainability [3, 7]. Previous studies during the Nyepi celebration have shown a significant reduction in electrical power usage that can be used to reduce emissions into the air [8].

By conducting an in-depth examination of air quality during Nyepi, this study contributes to the growing body of knowledge on the subject and provides insights into the immediate environmental changes that occur when human activities are temporarily halted. The focus on key pollutants, including carbon monoxide (CO), nitrogen dioxide (NO2), and dust particles, offers a comprehensive assessment of how these emissions respond to the unique circumstances of Nyepi. Additionally, this research evaluates the differential impact on air quality in various locations, encompassing both urban and suburban settings. Understanding the variations in air quality under these conditions is crucial for devising effective air quality management strategies in diverse environments. Moreover, the substantial reduction in PM2.5 concentrations observed during Nyepi underscores the potential benefits of periodic reductions in human activities for the environment, an area of growing interest in environmental science and policy development.

In this context, this research explores the changes in air quality during Nyepi, providing valuable insights into the relationship between human activities, pollutant levels, and air quality. These insights can inform the development of policies and practices aimed at improving air quality and mitigating the impact of air pollution on public health and the environment.

2 Methods

The research was conducted on the Indonesian island of Bali, specifically at three distinct locations: Denpasar Regional Office III, Karangasem Geophysics Post, and Jembrana Climatology Station. These locations were chosen to represent a range of urban and suburban environments (Figure 1). Data collection and measurements took place over 24 hours and 7 days, from February 28 to March 6, 2022. This period included Nyepi Day when all activities were suspended. Various instruments and devices were employed to collect air quality data. These instruments included gas analyzers for measuring pollutant gases like carbon monoxide (CO) and nitrogen dioxide (NO2), as well as equipment for measuring dust particle concentrations (Figure 2).

Data were collected at regular intervals throughout the 7 days. These intervals could vary based on the instrument and location, but the frequency of measurements was sufficient to capture variations in air quality during different times of the day. Collected data were subject to thorough analysis to assess the changes in air quality. The key variables of interest were

the concentrations of CO, NO2, and dust particles. The data were analyzed to determine relative reductions in these pollutant levels on Nyepi Day compared to the days before and after Nyepi.

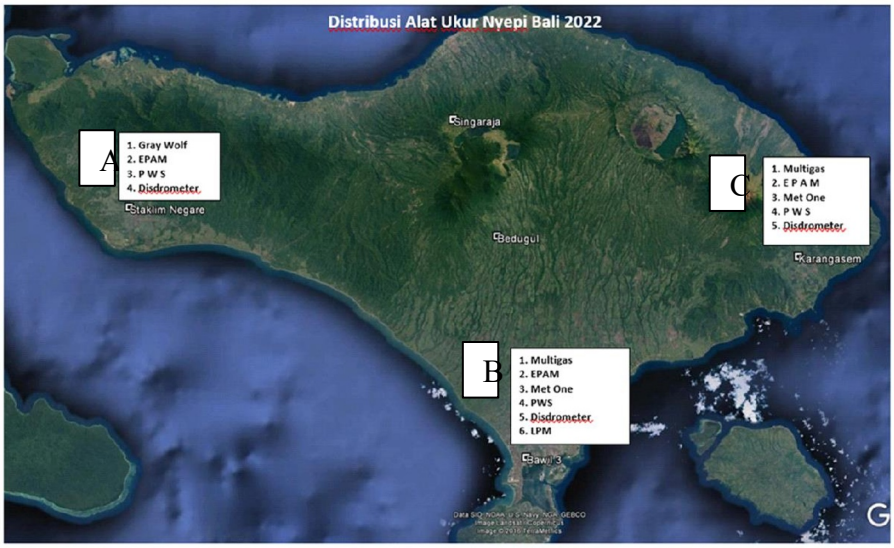

Fig. 1. Measurement locations: (A) Jembrana, (B) Denpasar, and (C) Karangasem.

Fig. 2. Measurement equipments: (a) EPAM-HAZDUST, (b) Sinyei Total Particulate, (c) Multi Gas Sensync, (d) Laser Precipitation Monitor, (e) Portable Weather System Multigas Obs, (f) Disdrometer, and (g) GrayWolf.

Statistical methods, such as mean values and percentages, were used to quantify and compare changes in pollutant concentrations. The study aimed to provide a quantitative assessment of the impact of Nyepi on air quality. The data were interpreted in the context of specific characteristics of each observation location. Factors like the sensitivity of the equipment, local human activity, and the proximity of measurement devices to pollutant sources were considered when explaining variations in air quality.

The research compared air quality data from Nyepi 2022 with historical data spanning 2020 to 2022 to gain a broader perspective. This allowed for an assessment of long-term changes in pollutant levels. A specific focus of the research was to analyze air quality during the nighttime, as this was when the most significant reduction in PM25 concentrations was observed. This aspect of the study could involve additional data collection and nighttime-specific analysis.

Ethical considerations may include obtaining necessary permissions to conduct research in specific locations, ensuring the safety of research personnel, and adhering to local regulations and cultural sensitivities associated with Nyepi. The findings were reported to facilitate clear understanding and interpretation, focusing on how the results contribute to the understanding of air quality changes during Nyepi and their broader implications for environmental policies and practices.

3 Results

3.1 CO

Carbon monoxide (CO) is a colorless, odorless and tasteless gas. CO consists of one carbon covalently bonded to one oxygen atom produced from the incomplete combustion of carbon compounds. CO is toxic to humans insofar as it forms a complex, displacing oxygen from the hemoglobin of the blood [4].

In this measurement, the tools used to measure carbon monoxide consist of several sources, namely Met One, Multigas Sensync, and Graywolf, which are placed at four observation locations. However, the data that meets the requirements for processing is only three locations: Denpasar, Karangasem, and Jembrana.

As an urban area, Denpasar has a very different pattern from the other 2 locations. Based on Figure 3, the pattern of increasing carbon monoxide generally starts at 07.00 in the morning and decreases in the afternoon until evening as human activity increases. However, during Nyepi, the concentration of carbon monoxide decreases, as seen from the graph on March 3, which tends to be lower than the days before and after Nyepi. Meanwhile, carbon monoxide measurements in Karangasem and Jembrana tend to be very low, and the pattern is less visible.

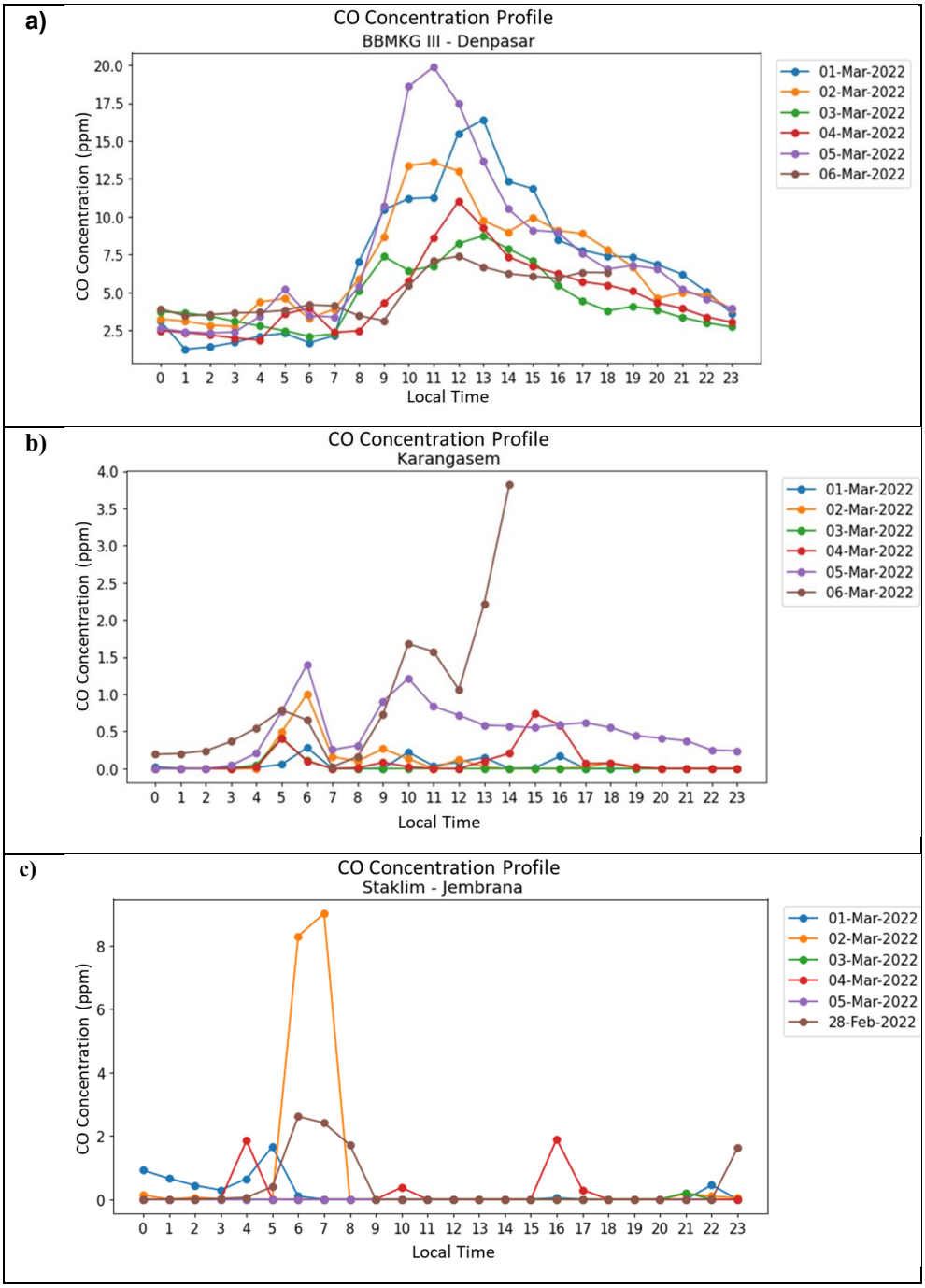

Fig. 3. CO gas profile at the measurement location (a. Denpasar, b. Karangasem and c. Jembrana).

3.2 NO_2

Nitrogen dioxide (NO2) is a toxic chemical compound with a strong odor and one of the primary air pollutants. The main natural sources of NO2 are forest fires and burning fossil

fuels, while anthropogenic sources come from motorized vehicles and industry. Exposure to NO2 at 376–18 800 μg/m3 (0.2–10 ppm) has affected pulmonary function in animal species like rats, mice, guinea pigs, and ferrets [5].

In general, NO2 gas concentrations increase in the morning and evening as human activity increases (Figure 4). However, the NO2 gas concentration measurements at three locations could not describe the differences between Nyepi and regular days.

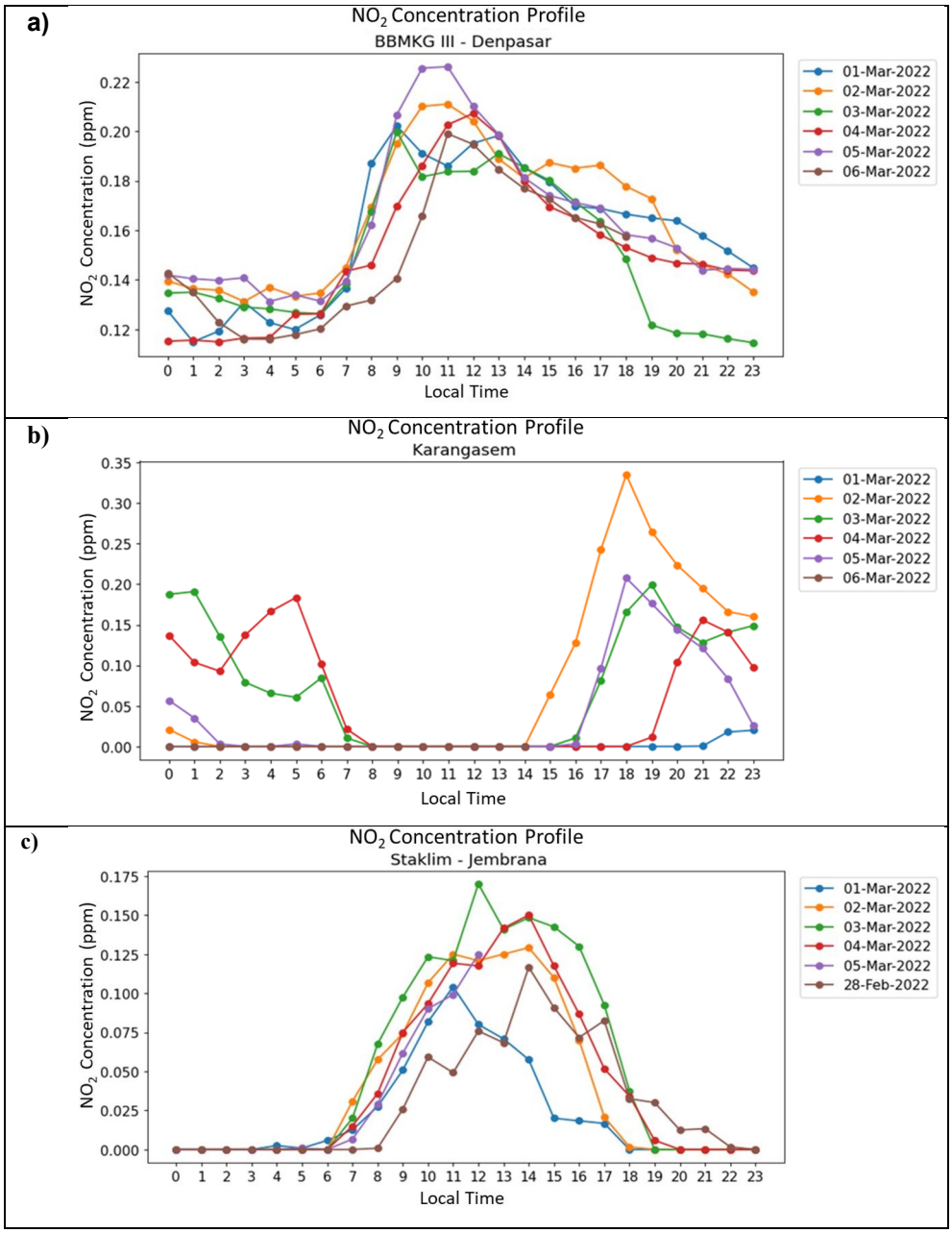

Fig. 4. NO_2 gas profile at the measurement location (a. Denpasar, b. Karangasem and c. Jembrana).

3.3 PM2.5

PM has wide-ranging deleterious effects on human health, particularly the cardiovascular system. Both acute and chronic exposure to PM air pollution is associated with an increased risk of death from cardiovascular diseases and has also been shown to be an important endocrine disruptor, contributing to the development of metabolic diseases such as obesity and diabetes mellitus, which themselves are risk factors for cardiovascular disease [6]. PM25 air quality parameters measured during Nyepi 2022 at the BMKG Region III Center showed lower data compared to the average for 2020 - 2022. The results are shown in Figure 5.

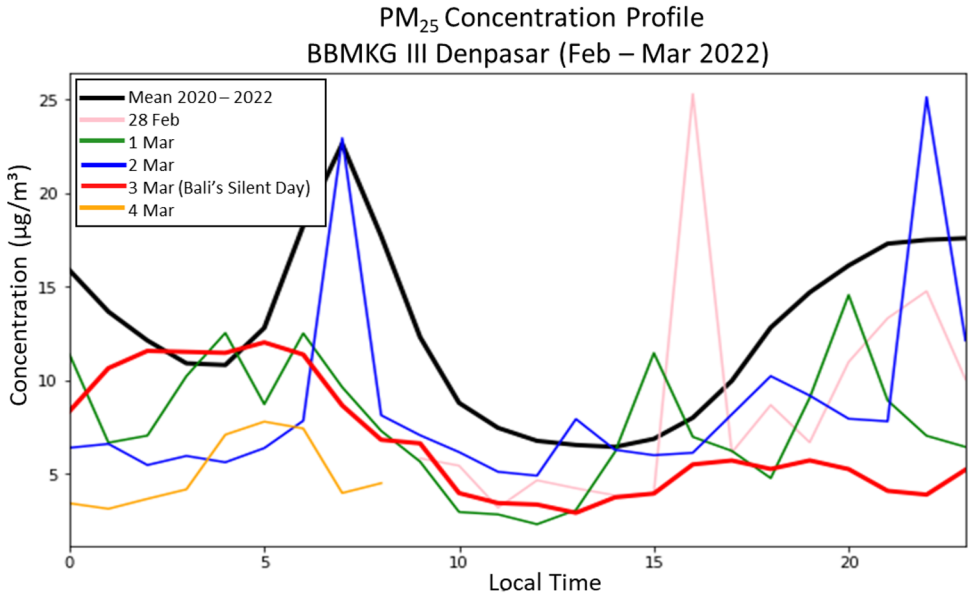

Fig. 5. $PM_{2.5}$ particulate profile before, during, and past Bali's Silent Day compared with their averages.

The difference between PM25 data during Nyepi 2022 and the average PM25 data for 2020 - 2022 shows decreased PM25 concentrations. The average decline is around 47%, with the highest decline at night. The graph of the difference between Nyepi 2022 data and the 2020-2022 average is shown in the following Figure 6.

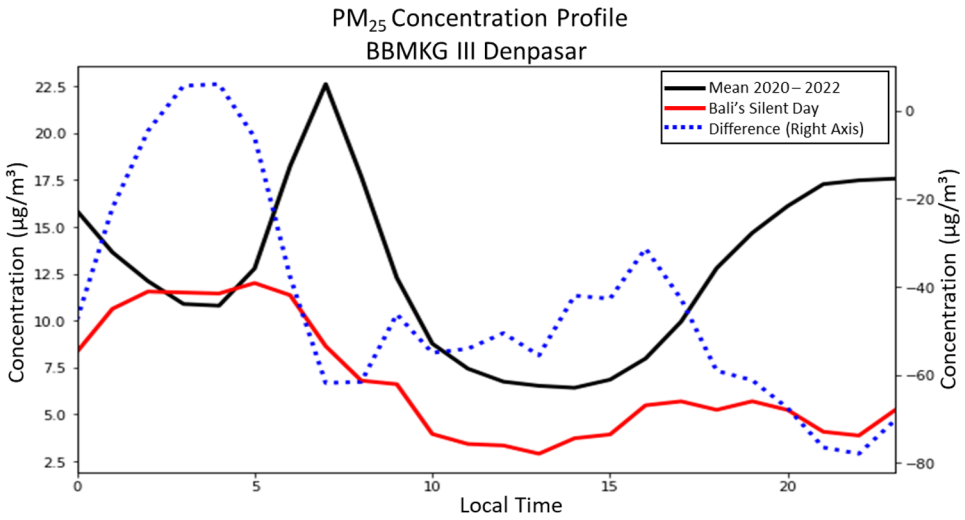

Fig. 6. Comparison of PM25 concentrations during Nyepi with the 2020 - 2022 average

4 Conclusion

The reduction in pollutant gas and dust particle concentrations varied depending on the sensitivity of the equipment, the character of each observation location, and the placement of measuring units. Compared to suburban areas, metropolitan areas with a high concentration of community activities have seen the largest improvement in air quality. The placement of measuring instruments near pollutant sources, especially in suburban regions, reduces pollutant gas concentrations comparable to urban areas. The difference in PM25 concentrations between Nyepi 2022 and the average PM25 for 2020 - 2022 is around 47%, with the greatest decline at night. Regarding the effectiveness of the Nyepi holiday in reducing pollutant concentrations, it is necessary to consider carrying out this activity sustainably by involving and collaborating with several related agencies.

Acknowledgement

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