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Comparative Assessment of Air Quality Index (AQI) during Pre-Diwali, Diwali and Post-Diwali Periods of 2024-2025 in Delhi, India: A Case Study

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Abstract

Objectives: This case study presents a comparative analysis of AQI trends in some selected sampling sites of Delhi, India, focusing on pollutants CO, SO_2, NO_2, NH_3, O_3, PM_{10}, and $PM_{2.5}$ during the pre-Diwali, Diwali, and post-Diwali periods, highlighting the limited research in this area. **Method:** The data required for the present investigation were collected from the website of CPCB under Ministry of Environment, Forest and Climate Change, Govt. of India. The periodical variation of the average AQI values is then critically analyzed and the ambient air quality at each sampling sites are categorized. **Findings:** This case study shows that in October 2024, the AQI reached a highest value of 433 at Anand Vihar on 16/10/2024, dominated by PM_{10}, followed by 392 at Rohini and 388 at Vivek Bihar on 24/10/2024, both governed by $PM_{2.5}$, which indicates a very poor air quality. In December 2024, the AQI levels intensified, peaking at 485 at Nehru Nagar on 19/12/2024, with $PM_{2.5}$ dominance across major stations (482 at Wazipur; 481 at Anand Vihar), reflecting a 12% increase with severe air quality conditions. By January 2025, peak AQI marginally declined to 472 at Vivek Bihar on 10/01/2025, showing a 3% reduction, though $PM_{2.5}$-driven pollution persisted within the very poor category. The study thus revealed that AQI value increases due to probable increased emissions of various types of fire crackers along with emissions from increased number of automobiles running as well. **Novelty:** The study provides a unique assessment of AQI dynamics during the pre-Diwali, Diwali, and post-Diwali periods, focusing on event-specific, multi-pollutant analyses. Unlike typical research, it examines short-duration, high-intensity pollution events linked to festive activities. By evaluating major gaseous pollutants and particulate matter across multiple stations, the research reveals localized pollution variations for event-based air quality management and policy interventions in urban areas.

Keywords: Air Quality; AQI; Air pollution; PM_{10}; $PM_{2.5}$

1 Introduction

Global air pollution, particularly in India, is a growing concern due to industrialization, rapid urbanization, infrastructure, and economic growth[1],[2]. Air pollution is caused by gases like CO, SO_2, NO_2, O_3, and NH_3 and particulate matter like PM_{10} and $PM_{2.5}$. These particles can cause respiratory issues and reduce visibility. Indian metropolitan cities are among the 20 most polluted globally. In 2015, India experienced a tragic loss of nearly 10 lakhs of lives due to particulate matter pollution[3]. Particulate matter is the primary pollutant contaminating air in India due to automobiles, industrial activities, and household activities[4]. Air pollution significantly increases the risk of heart stroke, heart-related diseases, acute respiratory diseases like lung cancer and asthma. Higher concentration of SO_2 and NO_2 in the atmosphere may exert serious effect on soil, water, and cropping pattern[5],[6]. Air pollution not only reduces atmospheric visibility but also alters the climate[7]. The quality of air within residential spaces even significantly impacts the health and overall well-being of those who reside there[8],[9].

The Air Quality Index (AQI) is a daily measure of air quality, estimating pollution and health impact, based on average sensor readings and may increase due to pollution activities. Pollutants detected include CO, O_3, NO_2, SO_2, PM_{10} and $PM_{2.5}$. Severe air pollutants in urban areas are being exacerbated by the rising levels of gases and particulate matter[10],[11]. The AQI may increase due to significant air pollution from construction, flyovers, and road widening activities, which contribute to the buildup of buildings and apartments[12] and excessive vehicle emissions and lack of rainfall contribute to pollution in the atmosphere, causing poor visibility and eye burns.

The AQI provides a straightforward, one (1) number one (1) color one (1) description for individuals to assess the air quality in their specific area which was launched by National Air Quality Index (NAQI) mission. The Central and State Pollution Control Boards (CPCB & SPCB) regularly conduct a National Air Monitoring Program (NAMP) that covers as much as two hundred forty cities across the country. For continuous monitoring of the real time data, authorized centers were established in several cities. The AQI has six categories, such as good, satisfactory, moderately polluted, poor, very poor, and severe. The proposed AQI covers eight pollutants viz CO, SO_2, NO_2, O_3, NH_3 Pb, PM_{10} and $PM_{2.5}$ for which short-term national air standards (average terms per hour) are set. Based on levels of these atmospheric pollutants and the associated standards, the potential health impacts are suggested for each of these pollutants for a particular range of AQI values. According to the initial inputs, the range of various AQI categories and the various pollutants and the potential health impacts for these pollutants are given in Table 1 and Table 2 respectively[13].

Table 1. The six categories of AQI range along with various pollutants

AQI Range	PM_{10} (μg/m^3) 24 h	$PM_{2.5}$ (μg/m^3) 24 h	NO_2 (μg/m^3) 24 h	O_3 (μg/m^3) 8 h	CO (μg/m^3) 8 h	SO_2 (μg/m^3) 24 h	NH_3 (μg/m^3) 24 h	Pb (μg/m^3) 24 h	Indicating Color
0-50	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5	Light Blue
51-100	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.5-1.0	Green
101-200	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0	Pink
201-300	251-350	91-120	181-280	169-208	10-17	381-800	801-1200	2.1-3.0	Yellow
301-400	351-430	121-250	281-400	209-784*	17-34	801-1600	1200-1800	3.1-3.5	Red
401-500	430+	250+	400+	784+	34+	1600+	1800+	3.5+	Maroon

Fireworks and firecrackers are extensively employed worldwide during many cultural, religious, and international events, as well as major global events that results in episodic atmospheric emissions. The Firework emissions consist of a complex mixture of oxidizers, colorants, binders, and metals, such as potassium chlorate, perchlorate, strontium carbonate, barium chlorate, copper (II) oxide, antimony trisulfide, aluminium, sulphur, potassium nitrate, shellac, dextrin, parlon, and mealed gunpowder along with particulate matters, which create dense particulate-laden atmospheric plumes[14],[15],[16] causing serious health problems. Delhi is already experiencing chronically degraded air quality; additional emissions from newly established industrial units-particularly sulfur dioxide (SO_2), nitrogen oxides (NO_x), fine and coarse particulate matter ($PM_{2.5}$ and PM_{10}), and volatile organic compounds (VOCs) further intensify ambient pollution levels[17],[18],[19]. Long-term exposure to PM2.5 is associated with respiratory diseases, including asthma, wheezing, cough, bronchitis, and lower respiratory infections[20],

Table 2. The six categories of AQI and the associated health effects of each category

AQI	Category	Associated health effects
0-50	Good	Lowest impact
51-100	Satisfactory	Sensitive people may have slight difficulty breathing.
101-200	Moderately polluted	Asthma, lungs and heart disease, children and orderly people with may suffer breathing.
201-300	Poor	Long time exposure may cause breathing difficulty, and heart disease.
301-400	Very poor	Long time exposure can develop respiratory diseases. Such affects may be prominent for people suffering from lung and heart disease.
401-500	Severe	Long time exposure may develop respiratory diseases even in healthy people as well, and may cause severe health issues in people suffering from lung and heart disease.

Source: Central Pollution Control Board, Ministry of Environment, Forests and Climate Change

lung cancer (LC), cardiovascular diseases, Parkinson's disease, and breast cancer[21],[22], the conditions leading to death[23]. This encounter is especially acute in densely populated regions and rapidly industrializing nations such as the USA, China, and India. Particulate matter (PM), a dominant air pollutant, poses a significant global public health risk due to its strong association with respiratory and cardiovascular morbidity[24].

Assessment of the AQI of a particular region is important parameter for taking action against the deterioration of quality of air and creating a public awareness. Although many investigations were conducted since long. However, the critical analysis and research on this particular issue in India is limited. In the year 2024, the celebration of Diwali was observed on 31/10/2024 and 01/11/2024. Diwali celebrations, while joyous, often lead to significant pollution, particularly air and noise pollution due to the widespread use of firecrackers. Firecrackers release harmful gases and particulate matter, contributing to smog and poor air quality. The risk of respiratory problems, allergies, and increased risk of cardiovascular diseases, respiratory issues as well as impact on ecosystem leads to conduct this investigation to assess the AQI during this period. In this case study, comparative analysis of the trends in AQI data in terms of some major gaseous pollutants and particulate matters in of one of the polluted city Delhi, India during pre-Diwali, Diwali and post Diwali periods is carried out to create an awareness about the AQI among the mass people regarding the probable health issues that might arise due to air pollution and suggest some effective measures in controlling the air quality index.

The study uniquely assesses air quality index (AQI) dynamics in Delhi by focusing on event-specific, multi-pollutant and station-wise evaluations during pre-Diwali, Diwali, and post-Diwali periods. It addresses short-duration, high-intensity pollution linked to festive activities, analyzing some major gaseous pollutants (CO, SO_2, NO_2, NH_3, and O_3) and particulate matter (PM_{10} and $PM_{2.5}$). The research reveals significant localized variations in pollution severity through multiple monitoring stations and presents a methodological framework that is replicable and scalable for use in other urban areas, aiding in event-based air quality management and policy development.

2 Methodology

In India, the ambient air quality data is collected through authorized stations, with State Pollution Control Boards and Pollution Control Committees assisting for uniformity and consistency. AQI monitoring sites collect 24-hour average concentration data for specific pollutants (8-hours in the case of CO and O_3). Sometimes data for the pollutants may not be monitored at the stations. The AQI is calculated based on data for the lowest three pollutants, including $PM_{2.5}$ and PM_{10}, which requires a minimum of 16 hours of data.

The concentrations of some major gaseous pollutants (CO, SO_2, NO_2, NH_3, and O_3) and particulate matter (PM_{10} and $PM_{2.5}$) required for the present investigation at ten different cites of the study area (shown in Figure 1) were collected from the website of CPCB[14] under Ministry of Environment, Forest and Climate Change (MoEFCC), Govt. of India. The periodical variation of the average AQI values during pre-Diwali, Diwali, and post-Diwali periods (from August, 2024 to January, 2025) were then critically analyzed and the ambient air quality at each sampling sites are categorized from which information regarding the status of the air quality is ascertained.

Study Area: Delhi, officially known as the National Capital Territory (NCT) of Delhi, is both a city and a union territory in India, encompassing New Delhi, the capital of India. It is a major metropolis on the Indo-Gangetic Plain, notable for its historical richness and cultural diversity. It serves as a political center with an urban population exceeding 28 million. Geographically, it

is located along the Yamuna River and borders Haryana and Uttar Pradesh, with coordinates approximately between 28°N to 29°N latitude and 76°E to 77°E longitude.
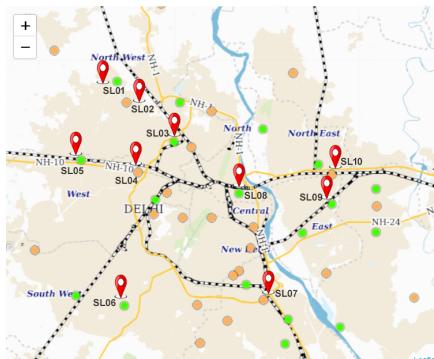

Fig 1. Map of the study area displaying sampling sites [25]

Delhi and New Delhi are often used interchangeably, but they are distinct entities. The National Capital Region includes the entire NCT and neighboring districts in neighboring states, including Ghaziabad, Noida, Greater Noida, Meerut, and Gurgaon, New Delhi, India's capital and part of the National Capital Territory, houses the Rashtrapati Bhavan, Sansad Bhavan, and Supreme Court. As a municipality, it is administered by the New Delhi Municipal Council.

3 Results and Discussion

The atmospheric air pollutant monitoring in terms of the AQI values of the sampling sites were conducted during a campaign focused on Diwali, covering pre-Diwali, Diwali day, post-Diwali, and control periods, to evaluate the effect of firecracker activities on air quality at selected sites. The month wise detail analysis of the same is discussed below.

3.1 Status of AQI in the month of August

In the month of August, the maximum AQI at SL-10 was reported as 234 on dated 23/08/2024 with PM-10 particles being the prominent one. Similarly, the maximum AQI values of the other three sampling stations were reported as follows: 138 on dated 31/08/2024 and 15/08/2024 at SL-2 and SL-3, followed by 136 on 25/08/2024 at SL-4 with prominent particles being $PM_{2.5}$ respectively. The variation of the highest and lowest AQI values in the month of August are shown in Figure 2. The overall AQI was found to be moderately polluted. This may be due to the immediate effect of monsoon that leads to slight reduction of the AQI values.
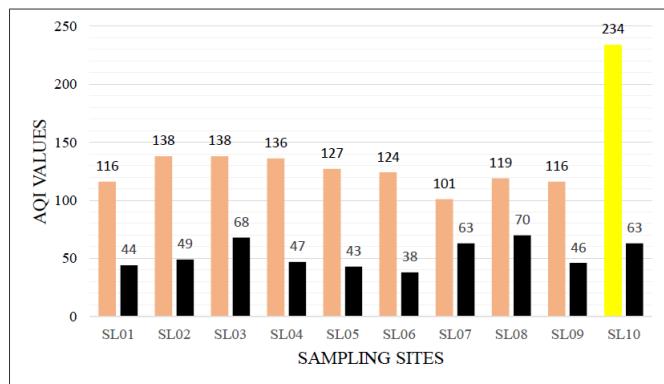

Fig 2. Variation of highest and lowest AQI values in the month of August

3.2 Status of AQI in the month of September

The variation of the highest and lowest AQI values in the month of September are shown in Figure 3. In the month of September, the maximum AQI was reported as 460 at SL-10 on dated 23/09/2024 with PM_{10} particles being the prominent one. Similarly, the maximum AQI values of the other sampling stations were reported as follows: 346 on dated 20/09/2024 at SL-8 with prominent particles being NO_2 followed by 302 on 24/09/2024 at SL-9 with prominent particles being $PM_{2.5}$ The overall AQI was found to be poor. It is observed that during the post-monsoon period, a significant increase in AQI values across all monitoring sites. The rise was primarily driven by elevated concentrations of $PM_{2.5}$ and PM_{10}, as the reduction in wet deposition coupled with ongoing anthropogenic emissions limited pollutant dispersion. Peak AQI values during this period reached the very poor to severe range, indicating substantial seasonal deterioration in air quality[26],[27].
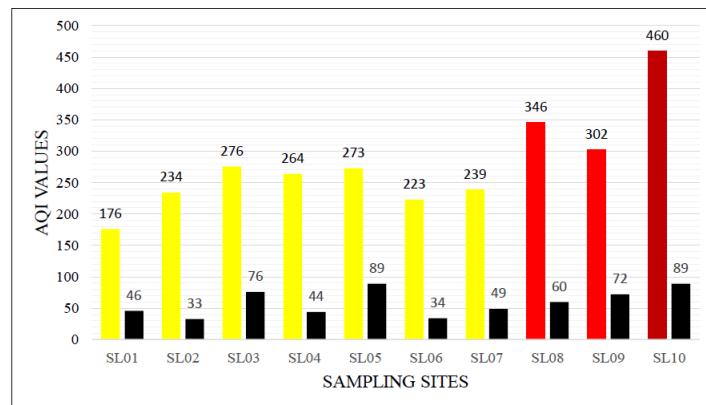

Fig 3. Variation of highest and lowest AQI values in the month of September

3.3 Status of AQI in the month of October:

In the month of October, the variation of the highest and lowest AQI values are shown in Figure 4. As seen in the figure, the maximum AQI was reported as 433 at SL-10 on dated 16/10/2024 with PM_{10} particles being the prominent. This was followed by 392 on dated 24/10/2024 at SL-2 with prominent particles being $PM_{2.5}$ and 388 on 24/10/2024 at SL-9 with prominent particles being $PM_{2.5}$. The overall AQI was found to be very poor.
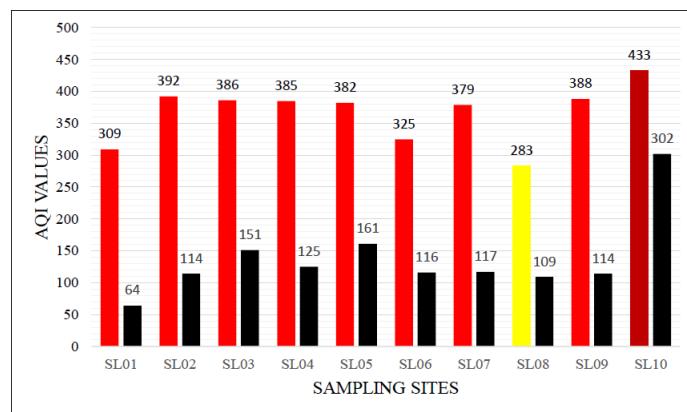

Fig 4. Variation of highest and lowest AQI values in the month of October

3.4 Status of AQI in the month of November

The variation of the highest and lowest AQI values in the month of November are shown in Figure 5. In this month the maximum AQI of most of the sampling stations gradually increases to 500 with prominent pollutants both PM_{10} and $PM_{2.5}$ on 19th and 18th November except at SL-1 and SL-8 where the AQI values are slightly lower. The overall air quality was found to be severely polluted.

3.5 Status of AQI in the month of December

The variation of the highest and lowest AQI values for the month of December are shown in Figure 6. As seen in the figure, the maximum AQI slightly decreases to 485 at SL-7 on dated 19/12/2024 with $PM_{2.5}$ particles being the prominent. This was followed by 482 on dated 19/12/2024 at SL-3with prominent particles being $PM_{2.5}$ and 481 on 18/12/2024 at SL-10 with prominent particles being $PM_{2.5}$. The overall AQI was found to be severe. In the year 2023 another such study revealed that AQI levels exhibit serious concern following Diwali, highlighting persistent challenges in festival-related air pollution mitigation. Some meteorological factors were also critical in modulating pollutant accumulation, with stagnant conditions such as low wind speeds, reduced mixing heights, and temperature inversions. The overall impact contributes to elevated pollutant concentrations[20]. It also may be noted that air pollution in India primarily stems from vehicle emissions, biomass burning, industrial discharges, and various minor sources, with significant exacerbation during Diwali due to firecracker use[28],[29].
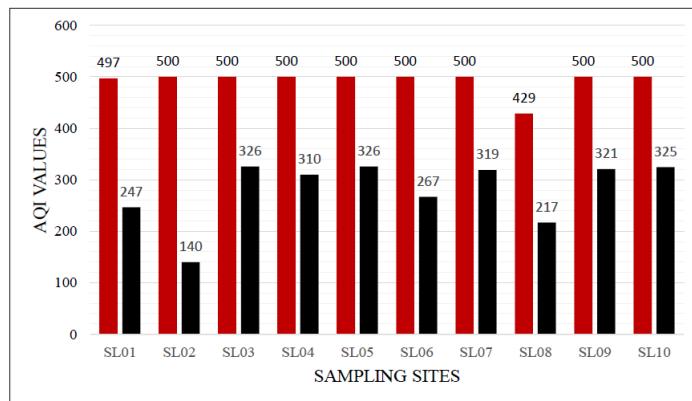

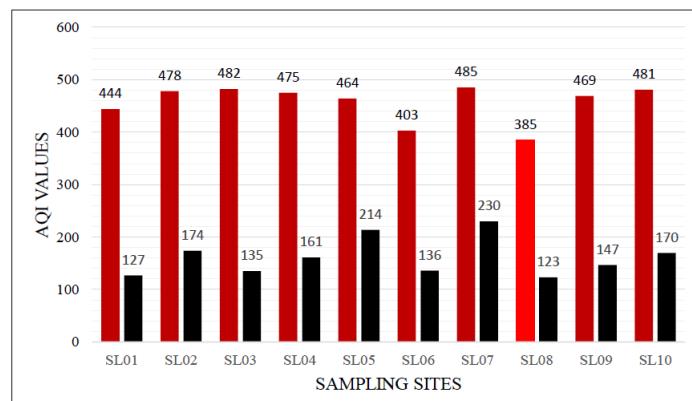**Fig 5.** Variation of highest and lowest AQI values in the month of November

Fig 6. Variation of highest and lowest AQI values in the month of December

3.6 Status of AQI in the month of January:

In the month of January, 2025, the variation of the highest and lowest AQI values are shown in Figure 7. As seen in the figure, the maximum AQI was further decreases to 472 at SL-09 on dated 10/01/2025 with $PM_{2.5}$ particles being the prominent. This was followed by 467 on dated 16/01/2025 at SL-3with prominent particles being $PM_{2.5}$ and 463 on 16/01/2025 at SL-2 with prominent particles being $PM_{2.5}$. Although, the overall AQI was found to be very poor, but the AQI values are lower than that observed in the month of December, 2024. Similar results are also observed where the AQI levels remained elevated for a few days post-Diwali before decreasing[30].
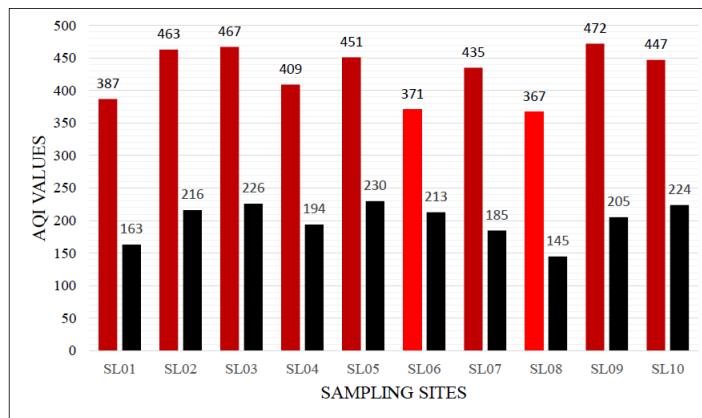

Fig 7. Variation of highest and lowest AQI values in the month of January

The overall results of this investigation are consistent with earlier studies reporting pronounced Diwali-related increases in air pollutants driven by intensive firecracker use and elevated vehicular emissions[16], [20]. Similar trends have been widely observed across Indian urban centers, where festival emissions coupled with unfavorable meteorological conditions lead to substantial short-term air quality deterioration[31]. The elevated pollutant levels during festivals like Diwali can worsen respiratory and cardiovascular issues, highlighting the need for effective regulatory measures and public awareness to safeguard public health during these events.

It is important to note that we all should be aware of the daily levels of air pollution, especially those suffering from diseases caused by exposure to polluted air. We need to be careful by monitoring the quality of AQI during this period of Diwali before going out of home. This is because during this period significant pollution particularly air and noise pollution due to the widespread use of firecrackers are observed. In 2022, several countries, including China, the USA, and Germany, implemented strict bans or penalties on firecrackers to combat pollution.

4 Conclusion

In India, various states such as Punjab, Delhi, West Bengal, Haryana, and Tamil Nadu have restricted or completely banned fireworks. Specifically, Delhi has prohibited the manufacturing, stockpiling, selling, and use of fireworks to minimize noise and air pollution. This case study on Delhi shows that in October 2024, the AQI reached a highest value of 433 at Anand Vihar on 16/10/2024, dominated by PM_{10}, followed by 392 at Rohini and 388 at Vivek Bihar on 24/10/2024, both governed by $PM_{2.5}$, which indicates a very poor air quality. In December 2024, the AQI levels intensified, peaking at 485 at Nehru Nagar on 19/12/2024, with $PM_{2.5}$ dominance across major stations showing 482 at Wazipur; 481 at Anand Vihar, that reflects a 12% increase with severe air quality conditions. By January 2025, peak AQI marginally declined to 472 at Vivek Bihar on 10/01/2025, showing a 3% reduction, though $PM_{2.5}$ driven pollution persisted within the very poor category. The authors suggest that the AQI value may have increased due to increased emissions of various types of fire crackers along with emissions from increased number of automobiles running as well. Air pollution can occur during this period (late October and early November) due particulate matter released from firecrackers and increased number of automobiles exhausts. This case study was conducted with respect to some the main air pollutants responsible for generating higher AQI and the data revealed that in most of the sampling stations with some of the pollutants under investigation, have shown a significant increase due to which the overall AQI levels was found to be in the severe range during this period. However, to achieve a more comprehensive understanding of pollution dynamics, future investigations should incorporate detailed temporal and spatial trend analyses of individual pollutant

concentrations, along with their relative contributions to AQI. Furthermore, extending this analytical framework to other cities and regions, and undertaking cross-national comparative studies over defined timeframes, would enable more robust assessments and facilitate the development of region-specific air quality management and mitigation strategies.

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6 Competing interests

The authors declare that there is no conflict of interest including any financial, personal or other relationships with other people or organizations that can influence this work.

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