Global Journal of Health Science; Vol. 16, No. 3; 2024
ISSN 1916-9736 E-ISSN 1916-9744
Published by Canadian Center of Science and Education

Impact of Burning Incense/Joss Paper on Outdoor Air Pollution: An Interrupted Time Series Analysis Using Hanoi Air Quality Data in 2020

Pham Thi Lan Chi[1], Vu Thi Hoang Lan[2], Le Tu Hoang[2], Le Thi Thanh Huong[3] & Bui Thi Tu Quyen[2]

[1] Faculty of Sciences, University of British Columbia, Vancouver. BC. Canada

[2] Faculty of Fundamental Sciences, Hanoi University of Public Health, Ha Noi, Vietnam

[3] Faculty of Environmental and Occupational Health, Hanoi University of Public Health, Ha Noi, Vietnam

Correspondence: Vu Thi Hoang Lan, Faculty of Fundamental Sciences, Hanoi University of Public Health. No. 1A Duc Thang Ward, North Tu Liem, Ha Noi, Vietnam. Tel: 84-91-835-8886. E-mail: vhl@huph.edu.vn

Received: January 21, 2024 Accepted: February 21, 2024 Online Published: February 26, 2024

doi:10.5539/gjhs.v16n3p27 URL: https://doi.org/10.5539/gjhs.v16n3p27

Abstract

Burning joss paper and incense during religious and cultural ceremonies is common in Vietnam. This study aims to measure the impact of burning joss paper and incense during Vu Lai festival (full moon of July) in Vietnam. Data of Hanoi air quality in year 2020 was used. Interrupted time series analysis was employed to examine the changes in pattern of various air quality indicators before and after the festival period.

The results revealed that burning joss paper and incense led to an immediate increase of 15.94 units in the air quality index on the first day, which gradually rose to 47.4 units by the end of the full moon period. Regarding NO_2, PM10, and PM25, there was no significant immediate change at the start of the intervention period (August 29th, 2020). However, significant increases in levels and an upward trend were observed during the intervention time, followed by substantial decreases after the intervention period ended (September 3rd, 2020). This analysis did not find a significant impact on CO, SO_2, and O_3 due to burning joss paper and incense.

These findings provide valuable insights for policymakers and stakeholders involved in managing and enhancing air quality in regions where such practices are prevalent.

Keywords: air pollution, incense, ITSA, joss paper, religious activities

1. Introduction

Burning joss paper and incense during religious and cultural ceremonies is common in many Asian cultures, including Vietnam (Giang et al., 2021; Yadav et al., 2020). These traditional practices may negatively impact air quality because burning joss paper/incense can release particulate matter into the air (Giang et al., 2021; B. Wang et al., 2007). Particulate matter is a mixture of solid and liquid particles suspended in the air, and when inhaled, it can cause respiratory problems such as coughing, wheezing, and shortness of breath. In addition to particulate matter, incense smoke can contain harmful chemicals like carbon monoxide, benzene, and formaldehyde (Dalibalta et al., 2015; Shen et al., 2017; Yadav et al., 2022).

Previous studies on joss paper and incense burning have focused mostly on examining the air quality of indoor or outdoor environments of certain places such as temples or pagodas (Chuang et al., 2012; Giang et al., 2021; Lui et al., 2016; Shen et al., 2017). One study conducted in Taiwan found that burning incense and other forms of indoor combustion, including cooking and smoking, contributed to high levels of particulate matter (PM2.5) in the air (Lee et al., 2021). Another study conducted in Hong Kong found that burning incense can release large amounts of pollutants, including carbon monoxide, nitrogen oxides, and sulfur dioxide, into the air (B. Wang et al., 2007). In Vietnam, a study conducted in Ho Chi Minh City found that burning joss paper and incense contributed to high levels of particulate matter in the air, particularly in homes where these practices were frequently conducted (Giang et al., 2021).

Hanoi, the capital of Vietnam, has been reported to have poor air quality. The high levels of pollutants in the air can have severe health impacts on the people who live there, including respiratory problems, heart disease, and cancer (Sakamoto et al., 2018). The poor air quality in big cities of Vietnam has been attributed to several main reasons, such as high population density, traffic congestion, industrial activities, and geographic location (Huu & Ngoc, 2021; Khuc et al., 2022). In addition to these well-known reasons, other daily human activities, such as burning joss/incense during long periods of religious ceremonies, can contribute to the overall outdoor air quality in Hanoi.

The full moon of July (Vu Lai festival) holds spiritual and religious significance in Vietnamese culture, leading to incense and joss paper burning for several days. The amount of joss paper burning on this occasion is considered the largest of the year (Giang et al., 2021). This prolonged period of burning joss paper during Vu Lai festival may have a more pronounced impact on outdoor air quality than at other times. Previous studies in different countries had reported the impact of burning incense on indoor air quality (Chuang et al., 2012; Dalibalta et al., 2015; Hu et al., 2009; Lui et al., 2016; B. Wang et al., 2007; Yadav et al., 2022). Still, little data is available about the contribution of burning joss/incense to the outdoor air quality. This study aims to explore and quantify the influence of burning joss paper and incense, specifically during the full moon of July, on outdoor air quality by using Hanoi data in the year 2020.

2. Methods

2.1 Data Sources

Data used in this analysis came from the Open Development Initiative (ODI) project (https://opendevelopmentmekong.net/). This project extracted data via api (https://api.waqi.info/), filtered and displayed the following historical air quality data for Vietnam: O3 (µg / m³), PM2.5 (µg / m³), PM10 (µg / m³), CO (µg / m³), NO_2 (µg / m³), SO_2 (µg / m³), location, province, city, update time, AQI indicator, reference link, pressure, humidity, temperature. The online dataset on air quality in Vietnam for the year 2020 was used (https://data.opendevelopmentmekong.net/dataset/timelines-dataset-on-air-quality-in-vietnam).

This dataset presents air quality measurements for various cities in Vietnam, including Hanoi. For the purposes of this study, data was specifically extracted for Hanoi city, covering a two-month period from August 1st to September 30th, 2020.

2.2 Measurement Definition

2.2.1 Dependent Variables

Overall quality index: calculated based on the levels of various pollutants present in the air, such as particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), and sulfur dioxide (SO_2). The AQI considers the concentrations of these pollutants and converts them into a single numerical value.

Particulate matter (Pm10/Pm25 µg/m³): refers to tiny particles that are suspended in the air, such as dust, dirt, and soot.

Ozone (03 µg/m³): Ozone is a gas that is formed when nitrogen oxides and volatile organic compounds (VOCs) react in the presence of sunlight.

Carbon Monoxide (CO µg/m³): Carbon monoxide is a colorless, odorless gas that is produced from incomplete combustion of fossil fuels.

Nitrogen Dioxide (NO_2 µg/m³): Nitrogen dioxide is a reddish-brown gas that is produced from burning fossil fuels.

Sulfur Dioxide (SO_2 µg/m³): Sulfur dioxide is a gas that is produced from burning fossil fuels that contain sulfur.

2.2.2 Evaluation Time Point

In the Lunar calendar of 2020, the full moon of July occurred on September 2nd. It is common for people to burn joss paper and incense as part of their cultural practices for a period of 4-5 days before the day of full moon. The impact of burning joss paper and incense can still be observed up to one day after September 2nd due to a lag effect. Hence, for this study, the designated "intervention" time in the Interrupted Time Series Analysis was defined as August 29th to September 3rd, 2020.

2.3 Statistical Analysis

Initially, descriptive statistics were computed for two distinct periods: the intervention time and the non-intervention time. Among the six dependent variables analyzed, the mean/median of two outcomes, namely CO and SpO_2, did not display any notable differences between the full moon and other periods. Thus, the study examined the potential impact of burning joss paper and incense during the Vu Lai festival on the remaining outcomes (Aqi, O_3, NO_2, PM10, PM25) using the Interrupted Time Series Analysis (ITSA) module in STATA. This analytical approach compared the patterns of the dependent variables before and after the intervention or event while accounting for underlying trends and seasonality (Linden, 2021)

The general equation for an Interrupted Time Series Analysis (ITSA) model can be represented as equation 1

$$Y = \beta0 + \beta1t + \beta2X + \beta3*(t*X) + \varepsilon \quad (1)$$

Where:

- *Y represents the outcome variable, or the dependent variable*
- *t is the time variable, representing the time points in the series.*
- *X is the binary intervention variable, indicating the presence (1) or absence (0) of the intervention at each time point.*
- *β0 is the intercept term, representing the expected value of Y when t and X are both zero.*
- *β1 is the slope term for the time variable, representing the baseline trend or change in Y over time in the absence of intervention.*
- *β2 is the coefficient for the intervention variable X, representing the immediate effect of the intervention on Y.*
- *β3 is the coefficient for the interaction term (t*X), capturing the sustained or long-term effect of the intervention on the trend of Y over time.*
- *ε represents the error term or residual, accounting for unexplained variation in Y that the model does not capture.*

To investigate the potential effects of burning joss paper and incense during this period on the dependent variables, the pattern of air quality index and other relevant factors were compared across three distinct periods: before August 29th, between August 29th and September 3rd, and after September 3rd. This analysis aimed to identify any significant impacts on the dependent variables resulting from burning joss paper and incense during the specified intervention timeframe.

3. Results

3.1 Descriptive Analysis

Table 1 presents the estimated mean and median for all air quality outcomes examined in this study. These values were estimated separately for "intervention time" (i.e., between August 29th and Sep 3rd, 2020) and "non-intervention time" (from August 1 to before August 29 and after Sep 3rd to Sep 30th). Both measures of central tendency show no differences between intervention time and non-intervention time for 2 air quality outcomes, CO and SO_2. For the other 4 outcomes, intervention time had higher both mean and median compared to non-intervention time.

Table 1. Descriptive analysis of air quality indicators during the Full moon of July period and other times

	Non-intervention time	***Intervention time***
Aqi		
Mean (SD)	28.60 (18.40)	70.67 (15.06)
Median (Q1, Q3)	24.0 (14.0, 39.0)	64.5 (59.0, 87.0)
CO		
Mean (SD)	24.45 (7.78)	22.00 (6.93)
Median (Q1, Q3)	24.0 (18.0, 30.0)	24.0 (14.0, 28.0)
NO_2		
Mean (SD)	6.72 (1.90)	10.00 (1.38)
Median (Q1, Q3)	6.4 (5.1, 7.4)	9.9 (9.0, 11.0)
O_3		
Mean (SD)	5.11 (2.17)	9.09 (3.51)
Median (Q1, Q3)	5.1 (3.6, 6.0)	8.1 (7.0, 11.9)

PM10		
Mean (SD)	20.40 (6.83)	36.00 (11.24)
Median (Q1, Q3)	20.0 (16.0, 23.0)	31.5 (27.0, 47.0)
PM25		
Mean (SD)	41.65 (15.46)	71.00 (22.85)
Median (Q1, Q3)	38.0 (29.0, 53.0)	64.5 (55.0, 89.0)
SO_2		
Mean (SD)	4.32 (0.77)	4.12 (0.24)
Median (Q1, Q3)	4.0 (4.0, 5.0)	4.0 (4.0, 4.1)

3.2 Assessing Changes in Overall Air Quality Index during Religious Periods

Table 2 displays the results of the ITSA model, examining the influence of burning joss paper and incense during the full moon of July period on the overall air quality indicators. The coefficient estimate for the change on August 29th, 2020, was 15.94 ($p<0.05$), signifying a statistically significant immediate effect of the intervention on AQI. Specifically, the intervention led to a significant increase of 15.94 units in AQI levels at the onset of the religious period, with the increase persisting until September 3rd. Furthermore, the coefficient estimate for the change on September 3rd, 2020, was -47.36 ($p<0.01$), indicating a substantial decrease in AQI levels after the conclusion of the religious period. These findings suggest that during the full moon period, the level of AQI was statistically higher than the rest of the study time. Figure 1a illustrates the patterns in AQI changes during and after the intervention period.

3.3 Assessing Changes in Level of PM10

Table 2 presents the outcomes of the ITSA model examining the impact of burning joss paper and incense during the full moon of July on PM10. The coefficient estimate on August 29th, 2020, was -2.14 ($p>0.05$), suggesting that there was no statistically significant change in Pm10 levels at the start of the intervention period.

However, the coefficient for changes in trend during the intervention period was 4.59 ($p<0.01$), indicating a significant increase in PM10 levels during the religious period. Both the coefficient for changes on September 3rd and changes in trend after September 3rd were statistically significant, implying a substantial decrease in Pm10 levels following the conclusion of the religious period. These findings indicate that during the full moon period, the levels of PM10 were statistically higher compared to the rest of the study duration. Figure 1b demonstrates the changes in PM10 during and after the intervention period.

3.5 Assessing Changes in the Level of PM25

Table 2 presents the ITSA for changes in the level of Pm25. The coefficients and p-value in this model were similar to the model for changes in the level of Pm10. Figure 1c also visualizes the changes in the value and trend of Pm25 for 3 periods: before, during, and after Full moon of July period. Both the statistical model and the graph indicated that the level of Pm25 was significantly higher during the Full moon period compared to other times of the study.

3.6 Assessing Changes in the Level of Ozone (O_3)

The coefficient estimate for the change on August 29th, 2020, was not statistically significant (Table 2). However, there was a positive change in trend after August 29th (1.13), which approached the level of significance ($p = 0.08$). After the intervention, there was a significant decrease in the level of O_3, as indicated by both the change and change in trend coefficients having p-values less than 0.05.

3.7 Assessing Changes in the Level of Nitrogen Dioxide (NO_2)

Table 2 presents the results of the ITSA model investigating the influence of burning joss paper and incense during the full moon of July on NO_2. The coefficient estimate on August 29th, 2020, was 0.33 ($p>0.05$), suggesting that there was no statistically significant change in NO_2 levels at the beginning of the intervention period.

However, during the intervention period, there was a significant increase in NO_2 levels, as the coefficient for changes in trend was 0.59 ($p<0.01$). This indicates a significant upward trend in NO_2 levels during the religious period. Both the coefficient for changes on September 3rd and changes in trend after September 3rd were statistically significant, indicating a substantial decrease in NO_2 levels after the intervention stopped. These findings highlight that the levels of NO_2 were statistically higher during the full moon period compared to the rest of the study duration. To visualize these changes, refer to Figure 1d, which illustrates the patterns in NO_2 levels during and after the intervention period.

Table 2. Changes in Air quality indicators due to impact of burning joss paper/incense during Full Moon of July period

	Coefficient [95%CI]				
	Air quality index	***PM10***	***PM25***	***O_3***	***NO_2***
Trend before 29/08/2020	0.19 [-0.62, 0.99]	0.41*** [0.11, 0.71]	0.47 [-0.31, 1.24]	0.06 [-0.04, 0.16]	0.09*** [0.03, 0.16]
Change at 29/08/2020	15.94** [0.37, 31.51]	-2.14 [-8.49, 4.22]	-8.66 [-21.53, 4.22]	-0.54 [-2.81, 1.73]	0.33 [-0.83, 1.48]
Change in trend at 29/08/2020	4.31 [-2.24, 10.86]	4.59*** [1.37, 7.82]	13.03*** [7.69, 18.38]	1.13* [-0.12, 2.37]	0.59*** [0.48, 0.69]
Change at 03/09/2020	-47.36*** [-68.83, -25.90]	-20.61*** [-31.49, -9.73]	-61.27*** [-80.49, -42.06]	-4.82** [-8.95, -0.69]	-2.69*** [-4.30, -1.08]
Change in trend at 03/09/2020	-5.53 [-12.50, 1.43]	-5.48*** [-8.87, -2.09]	-13.79*** [-19.51, -8.07]	-1.38** [-2.66, -0.11]	-0.82*** [-0.97, -0.67]
Intercept	37.16*** [26.82, 47.49]	14.54*** [11.34, 17.74]	35.91*** [24.18, 47.65]	4.98*** [3.94, 6.03]	5.28*** [4.14, 6.42]

*** p<.01, ** p<.05, * p<.1.

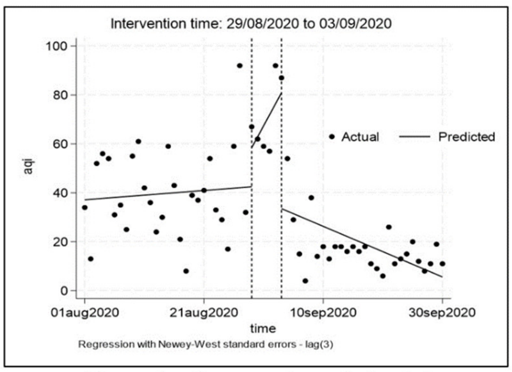

Figure 1a: Post-trend graph for Aqi

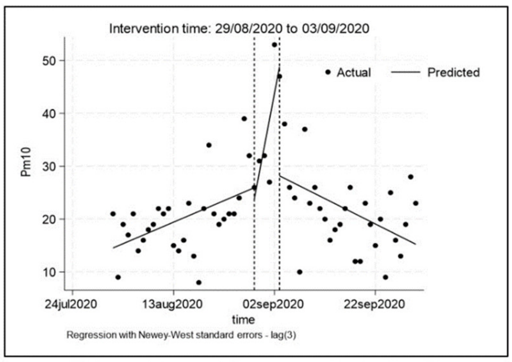

Figure 1b: post-trend graph for Pm10

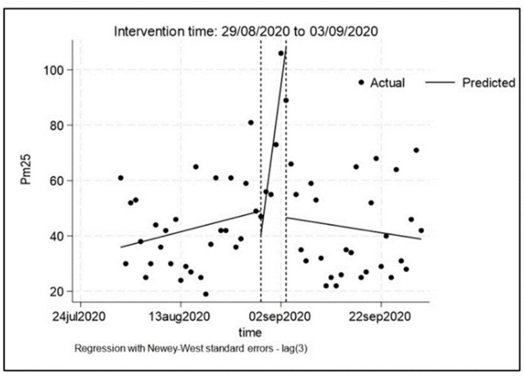

Figure 1c: Post-trend graph for Pm25

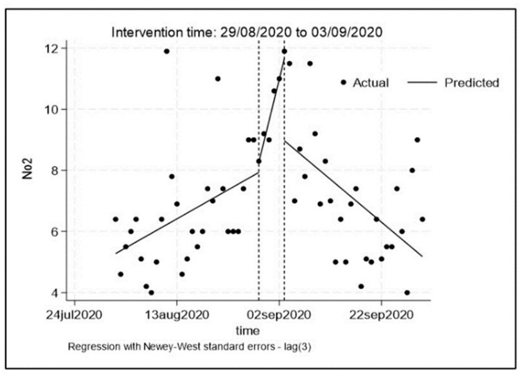

Figure 1d: Post-trend graph for N02

Figure 1. Post-trend of air quality indicators after Vu Lai festival

4. Discussion

The present study examined the influence of burning joss paper and incense during long period (i.e., Vu Lai festival) on outdoor air quality in Hanoi. Using data from the year 2020, this study applied ITSA approach, which considered burning joss paper/incense as an "intervention" and the intervention time as 6 days around the Full moon of July in Lunar calendar (August 29th to Sep 3rd, 2020). Results provide evidence of the potential impact of burning joss paper and incense on various air quality indicators. Regarding the overall air quality index (AQI), the ITSA model demonstrated a statistically significant immediate increase in AQI levels on August 29th, 2020. This increase persisted until September 3rd, indicating that the intervention had a notable impact on the overall air quality during the full moon period. Furthermore, a substantial decrease in AQI levels was observed after the conclusion of the religious period. For three outcomes, Pm10, Pm25, and NO2, the ITSA model revealed the same patterns, no significant immediate change at the start of the intervention period (i.e., August 29th, 2020), significant increases in levels and upward trend during the intervention time and substantial decreases after the intervention time finish (Sep 3rd, 2020). For other air quality indicators such as CO, SO_2, O_3, the study did not find significant changes in these indicators during the intervention period.

Previous studies had reported the immediate impact of burning joss paper/incense on indoor air quality (Chuang et al., 2012; Hsueh et al., 2012; Khezri et al., 2015; Lee et al., 2021; Lui et al., 2016; Shen et al., 2017; B. Wang et al., 2007; Yadav et al., 2022). The impact on air quality from burning joss paper and incense may vary depending on factors such as the duration and intensity of burning, the type of materials burned, and the ventilation in the area (Chuang et al., 2012; Khezri et al., 2015; Lee et al., 2021; Lin et al., 2008). The concentration of pollutants released from the burning materials tends to be higher within the confined area. This can lead to a more significant impact on indoor air quality compared to outdoor environments, where pollutants disperse more readily. Joss paper is typically crafted from resources like bamboo or recycled paper. The main chemical makeup of joss paper consists of approximately 45% oxygen, 40% carbon, 5% hydrocarbon, and minor quantities of nitrogen, sulfur, and chlorine (Lin et al., 2008). Joss papers are widely produced in Vietnam by numerous paper mills that often utilize old machines and outdated technology (Giang et al., 2021). This study showed that when burning joss paper/incense happened for a long period (i.e., 5-6 days as in the full moon of July period), the cumulative effect of these practices can contribute to increased levels of pollutants in the air, affecting outdoor air quality. According to the ITSA model, burning joss paper/incense resulted in an immediate increase of 15.94 units in the air quality index level on the first day, gradually rising to 47.4 units by the end of the full moon of July period.

Air quality is influenced by various determinants, encompassing weather conditions, geographical factors, and human activities. It is crucial to control for these diverse factors when studying air quality (K. Wang et al., 2019). As we relied on secondary data, certain information was unavailable. However, our analysis intentionally focused on the year 2020 due to the unprecedented circumstances brought about by the COVID-19 pandemic, resulting in lockdown measures in Hanoi. This led to a significant reduction in overall human activities, including traffic, industrial operations, and daily routines, which helped mitigate potential confounding factors. By utilizing the 2020 dataset, our goal was to isolate the influence of burning joss paper and incense during religious festivals on air quality, as other contributing factors were comparatively subdued during the lockdown periods. This approach enhances the precision of our study, facilitating a more focused examination of the specific impact of religious practices on air quality in Hanoi. However, it is important to note that due to COVID-19 social distancing measures, the amount of joss paper/incense burned during the full moon of July in 2020 may have been lower than usual, potentially resulting in an underestimation of impacts. Additionally, our analysis concentrated on a specific short period (August 29th to September 3rd, 2020) to account for significant fluctuations in weather conditions.

This study used the ITSA approach. This model was applicable because there was a clear point in time where an intervention/event occurred, and the intervention was expected to have an immediate or gradual effect on the variable of interest. Most importantly, ITSA employs statistical techniques that account for autocorrelation and potential dependence within the time series data. By considering the pre-existing trajectory of the outcome variable, ITSA helps to disentangle the intervention's effect from other long-term changes in the data and provides a solid foundation for drawing conclusions from the analysis (Ewusie et al., 2020).

Overall, the findings of this study emphasize the potential impact of cultural practices, specifically the burning of joss paper and incense during a long religious period, on outdoor air quality in Hanoi. These findings contribute to our understanding of the relationship between cultural practices and air pollution, providing insights for policymakers and stakeholders in managing and improving air quality in regions where such practices are prevalent.

In conclusion, this study demonstrated the application of ITSA approach in examining the effects of a certain event on air quality as well as provided evidence about the potential impacts of burning joss paper/incense during an extended religious period on outdoor quality. These findings shed light on the connection between religious practices and air pollution, offering valuable insights for policymakers and stakeholders involved in the management and enhancement of air quality in areas where these practices are common. By recognizing the potential impact of religious practices on air pollution, policymakers and stakeholders involved in the management and enhancement of air quality in areas can develop appropriate activities to promote healthier environments for communities engaging in these traditions.

Funding

None.

Provenance and Peer Review

Not commissioned; externally double-blind peer reviewed.

Data Availability Statement

The data that support the findings of this study are available on request.

Competing Interests Statement

The authors declare that there are no competing or potential conflicts of interest.

References

Chuang, H.-C., Jones, T., & BéruBé, K. (2012). Combustion particles emitted during church services: Implications for human respiratory health. *Environment International*, *40*, 137-142. https://doi.org/10.1016/j.envint.2011.07.009

Dalibalta, S., Elsayed, Y., Alqtaishat, F., Gomes, I., & Fernandes, N. (2015). A health risk assessment of Arabian incense (Bakhour) smoke in the United Arab Emirates. *Science of The Total Environment*, *511*, 684-691. https://doi.org/10.1016/j.scitotenv.2014.12.024

Ewusie, J. E., Soobiah, C., Blondal, E., Beyene, J., Thabane, L., & Hamid, J. S. (2020). Methods, Applications and Challenges in the Analysis of Interrupted Time Series Data: A Scoping Review. *Journal of Multidisciplinary Healthcare*, *13*, 411-423. https://doi.org/10.2147/JMDH.S241085

Giang, L. V., Thanh, T., Hien, T. T., Tan, L. V., Thi Bich Phuong, T., & Huu Loc, H. (2021). Heavy metals emissions from joss paper burning rituals and the air quality around a specific incinerator. *Materials Today: Proceedings*, *38*, 2751-2757. https://doi.org/10.1016/j.matpr.2020.08.686

Hsueh, H. T., Ko, T. H., Chou, W. C., Hung, W. C., & Chu, H. (2012). Health risk of aerosols and toxic metals from incense and joss paper burning. *Environmental Chemistry Letters*, *10*(1), 79-87. https://doi.org/10.1007/s10311-011-0331-5

Hu, M.-T., Chen, S.-J., Huang, K.-L., Lin, Y.-C., Chang-Chien, G.-P., & Tsai, J.-H. (2009). Characterization of polychlorinated dibenzo-p-dioxin/dibenzofuran emissions from joss paper burned in a furnace with air pollution control devices. *Science of The Total Environment*, *407*(10), 3290-3294. https://doi.org/10.1016/j.scitotenv.2009.01.037

Huu, D. N., & Ngoc, V. N. (2021). Analysis Study of Current Transportation Status in Vietnam's Urban Traffic and the Transition to Electric Two-Wheelers Mobility. *Sustainability*, *13*(10), Article 10. https://doi.org/10.3390/su13105577

Khezri, B., Chan, Y. Y., Tiong, L. Y. D., & Webster, R. D. (2015). Annual air pollution caused by the Hungry Ghost Festival. *Environmental Science: Processes & Impacts*, *17*(9), 1578-1586. https://doi.org/10.1039/C5EM00312A

Khuc, Q. V., Nong, D., & Phu Vu, T. (2022). To pay or not to pay that is the question - for air pollution mitigation in a world's dynamic city: An experiment in Hanoi, Vietnam. *Economic Analysis and Policy*, *74*, 687-701. https://doi.org/10.1016/j.eap.2022.03.023

Lee, C.-W., Vo, T. T. T., Wee, Y., Chiang, Y.-C., Chi, M.-C., Chen, M.-L., Hsu, L.-F., Fang, M.-L., Lee, K.-H., Guo, S.-E., Cheng, H.-C., & Lee, I.-T. (2021). The Adverse Impact of Incense Smoke on Human Health: From Mechanisms to Implications. *Journal of Inflammation Research*, *14*, 5451-5472. https://doi.org/10.2147/JIR.S332771

Lin, M.-D., Rau, J.-Y., Tseng, H.-H., Wey, M.-Y., Chu, C.-W., Lin, Y.-H., Wei, M.-C., & Lee, C.-H. (2008).

Characterizing PAH emission concentrations in ambient air during a large-scale joss paper open-burning event. *Journal of Hazardous Materials*, *156*(1), 223-229. https://doi.org/10.1016/j.jhazmat.2007.12.015

Linden, A. (2021). ITSA: Stata module to perform interrupted time series analysis for single and multiple groups. *Statistical Software Components*. https://ideas.repec.org//c/boc/bocode/s457793.html

Lui, K. H., Bandowe, B. A. M., Ho, S. S. H., Chuang, H.-C., Cao, J.-J., Chuang, K.-J., Lee, S. C., Hu, D., & Ho, K. F. (2016). Characterization of chemical components and bioreactivity of fine particulate matter (PM2.5) during incense burning. *Environmental Pollution*, *213*, 524-532. https://doi.org/10.1016/j.envpol.2016.02.053

Sakamoto, Y., Shoji, K., Bui, M. T., Phạm, T. H., Vu, T. A., Ly, B. T., & Kajii, Y. (2018). Air quality study in Hanoi, Vietnam in 2015-2016 based on a one-year observation of NOx, O3, CO and a one-week observation of VOCs. *Atmospheric Pollution Research*, *9*(3), 544-551. https://doi.org/10.1016/j.apr.2017.12.001

Shen, H., Tsai, C.-M., Yuan, C.-S., Jen, Y.-H., & Ie, I.-R. (2017). How incense and joss paper burning during the worship activities influences ambient mercury concentrations in indoor and outdoor environments of an Asian temple? *Chemosphere*, *167*, 530-540. https://doi.org/10.1016/j.chemosphere.2016.09.159

Wang, B., Lee, S. C., Ho, K. F., & Kang, Y. M. (2007). Characteristics of emissions of air pollutants from burning of incense in temples, Hong Kong. *Science of The Total Environment*, *377*(1), 52-60. https://doi.org/10.1016/j.scitotenv.2007.01.099

Wang, K., Yin, H., & Chen, Y. (2019). The effect of environmental regulation on air quality: A study of new ambient air quality standards in China. *Journal of Cleaner Production*, *215*, 268-279. https://doi.org/10.1016/j.jclepro.2019.01.061

Yadav, V. K., Choudhary, N., Heena Khan, S., Khayal, A., Ravi, R. K., Kumar, P., Modi, S., & Gnanamoorthy, G. (2020). Incense And Incense Sticks: Types, Components, Origin and Their Religious Beliefs and Importance Among Different Religions. *Journal of Bio Innovation*, *9*(6), 1420-1439. https://doi.org/10.46344/JBINO.2020.v09i06.28

Yadav, V. K., Malik, P., Tirth, V., Khan, S. H., Yadav, K. K., Islam, S., Choudhary, N., Inwati, G. K., Arabi, A., Kim, D.-H., & Jeon, B.-H. (2022). Health and Environmental Risks of Incense Smoke: Mechanistic Insights and Cumulative Evidence. *Journal of Inflammation Research*, *15*, 2665-2693. https://doi.org/10.2147/JIR.S347489

Copyrights