Reviewer #2:

We do appreciate your constructive and useful comments. To better reply to your overall comments in your long paragraph, we have divided your comments into serval parts with superscript [a], [b], [c], etc., and correspondingly addressed your comments in a separate paragraph [a, b], etc. More detailed replies are shown in your specific comments. To facilitate your review, the comments are in black, and the responses are in blue.

Overall comment:

The COVID-19 lockdown measures provide a natural experiment for probing air quality changes under substantial emission reductions. Zhang et al. investigate the variations of VOCs in response to the policy-driven emission changes in Zhengzhou city of China by using online ambient measurements, and the PMF model. [a]While this paper is within the scope of ACP, the present manuscript is limited to a cursory data analysis (simply reporting measurement results), without convincing evidence and in-depth discussion, which makes this paper unpublishable in the present form. [b]Further, the innovation of this work is far below the standard required to be published on ACP, which is even not qualified as a measurement report. [c]Though addressing the specific comments below may improve the paper, I don’t think these improvements could justify publication in a high-standard journal such as ACP. Concerning the major flaws and the lack of innovation, I think this paper should be rejected.

[a]While this paper is within the scope of ACP, the present manuscript is limited to a cursory data analysis (simply reporting measurement results), without convincing evidence and in-depth discussion, which makes this paper unpublishable in the present form.

We extend our heartfelt appreciation for your insightful comments. In response, we are committed to augmenting the manuscript with a more rigorous quantitative analysis and a profound exploration of the subject matter. Additionally, we undertook a comprehensive overhaul of the article to elevate its scholarly merit and overall quality.

We are sorry for the unclear and confusing statements in our original draft. Initially we had many cases (5 cases) in different studied periods exhibiting $PM_{2.5}$ pollution, and did not clearly explain why only discussing Case 1 and 3. We also did not clearly state the infection and recovery periods. These shortcomings including the annotations in Fig. 1 certainly confuse readers/reviewers.

Due to the lack of sufficient sampling days in other cases, we only discuss VOCs, and to a lesser extent, $PM_{2.5}$ changes in two major cases (Case 1 and 2 which is previous Case 3) along with clean days as well as infection and recovery periods; all due to the impact of ending China's zero- COVID policy.

In the analysis section of the results discussion, we added quantitative analyses of the main VOC and SOAP species for the clean days and for the two pollution processes; in the PMF source analysis section we added CPF plots and in the supplementary Materials added plots of daily trends in the source analysis results, as well as the rationale for the selection of the PMF factors. The results of the infection period and the recovery period are also compared according to the updated VOCs source analysis results. In addition, the correlation analysis between meteorological conditions and pollutant concentrations, the analysis of potential pollution sources, the PMF factor profiles of different pollution processes, and the concentrations of the main tracers of different processes are added in the supplementary materials, which provide a more scientific basis for the conclusions in our manuscript.

[b]Further, the innovation of this work is far below the standard required to be published on ACP, which is even not qualified as a measurement report.

It is our fault not to clearly show the rationale for our study. This research investigation is centered on the examination of the fluctuations in VOCs and $PM_{2.5}$ pollution levels within Zhengzhou, following the relaxation of COVID-19 control measures with the emergence of COVID-19 variant.

While some atmospheric VOC studies involving the impact of Covid-19 lockdown have been performed in India (Singh et al., 2023a), in China (e.g., Pei et al., 2022; Jensen et al., 2023; Zuo et al., 2024), or with respect to BETX only (e.g., Sahu et al., 2022; Singh et al., 2023b), a gap persisted in the investigation of VOCs due to the impact of abolishment of China's zero-policy. Furthermore, the present study is focused on the period dominated by the COVID-19 Omicron variant, which exhibited distinct characteristics in terms of geographical spread, infected population size, and symptomatology compared to earlier strains (Petersen et al., 2022; Merino et al., 2023). This period also witnessed substantial alterations in China's pandemic zero-Covid control policy, resulting in significant changes in societal activities (Figure 1). Consequently, this study aims to a detailed examination of how the alteration influenced atmospheric pollution, particularly regarding VOCs.

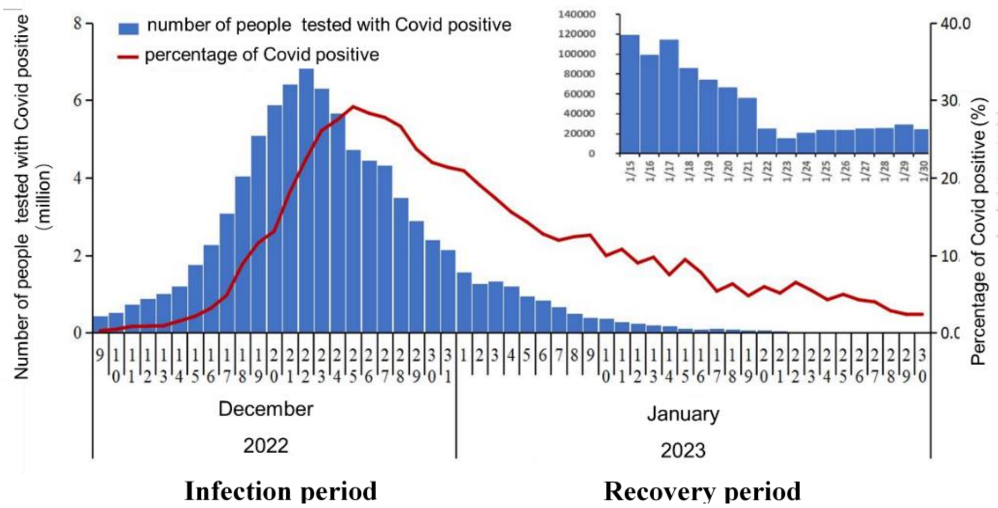

Figure 1. Trend of Omicron infection in China from 9 Dec. 2022 to 1

Jan. 2023 (CCDCP, 2023)

The shadow section in Figure 2 represents two haze pollution events during the monitoring period. A pollution event is determined when the daily average concentration of $PM_{2.5}$ exceeds 75 μg/m^3 (China's II-level standard) for at least three consecutive days. We apologize for the unclear statement and recognize that the original annotations might confuse readers, so we simplify the labeling in Figure 2. To avoid misinterpretation, we deleted processes with no more than 3 days of continuous contamination in Figure 2. In the revised version, we focus on the distinct characteristics of Case 1, Case 2, and Clean days as depicted in the figure. Case 1 (December 5 to December 10 with daily average $PM_{2.5}$ = 142.5 μg/m^3) and Case 2 (January 1 to January 8 with daily average $PM_{2.5}$ = 181.5 μg/m^3) were selected as they represent the pollution events in infection and recovery periods, respectively, due to their long duration and high pollution levels. We divided this period into an infection period (1-30 December 2022) and a recovery period (1 January 2023-31 January 2023) based on Chinese Center for Disease Control and Prevention's December 2022-January 2023 infection data statistics (Figure 1). Any days with a $PM_{2.5}$ concentration lower than 35 μg/m^3 (China's I-level standard) is considered as Clean days.

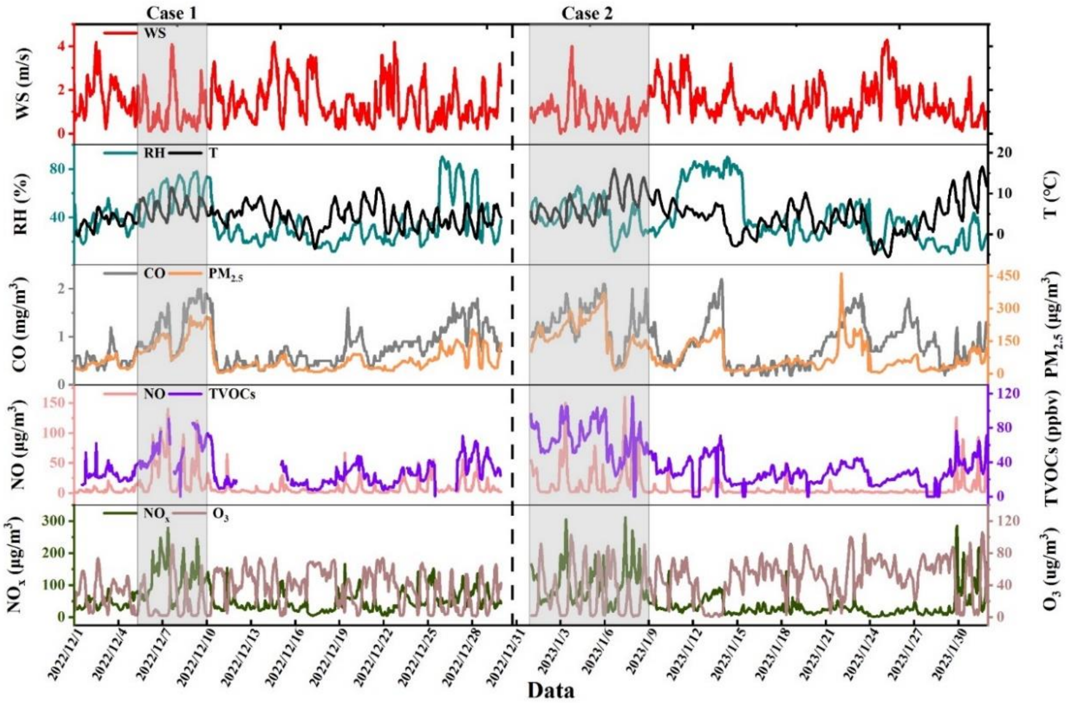

Figure 2. Time series of WS, WD, T, RH, CO, $PM_{2.5}$, NO, TVOCs, NO_x and O_3 during the observation period.

The above definition of pollution process will be incorporated into the revised manuscript.

References:

Jensen et al., 2023. Measurements of Volatile Organic Compounds During the COVID-19 Lockdown in Changzhou, China.

Pei et al., 2022. Decrease in ambient volatile organic compounds during the COVID-19 lockdown period in the Pearl River Delta region, south China.

Sahu et al., 2022. Impact of COVID-19 Pandemic Lockdown in Ambient Concentrations of Aromatic Volatile Organic Compounds in a Metropolitan City of Western India.

Singh et al., 2023a. Substantial Changes in Selected Volatile Organic Compounds (VOCs) and Associations with Health Risk Assessments in Industrial Areas during the COVID-19 Pandemic.

Singh et al., 2023b. Distribution and temporal variation of total volatile organic compounds concentrations associated with health risk in Punjab, India

Zuo et al., 2024. Pollution characteristics and source differences of VOCs before and after COVID-19 in Beijing

Merino et al., 2023. Evaluating the spread of Omicron COVID-19 variant in Spain

Petersen et al., 2022. Clinical characteristics of the Omicron variant - results from a Nationwide Symptoms Survey in the Faroe Islands, International Journal of Infectious Diseases,

[c]The major flaws and the lack of innovation.

The rationale for our study involved three major tasks: (1) Omicron variant; (2) abolishment of China’s zero policy; and (3) detailed

$VOC/PM_{2.5}$ analysis. To our best knowledge this is the first attempt to evaluate the Omicron variant impact of ending China's zero-Covid policy on ambient VOCs and $PM_{2.5}$. We do hope that through refining and overhauling the article's content, we can deepen our analysis/discussion and potentially alter your negative view.

Please refer to the above brief rationale (innovation) for our study. We will try to explain the innovation of our work in more details below.

China lifted the zero-COVID strategies, notably by announcing the '10 measures' about the optimization of COVID-19 rules on 7 December 2022 (Xinhua, 2022). After that, China experiences a nationwide outbreak of COVID-19. Leung et al. (2023) estimated that the cumulative infection attack rate in Beijing was 75.7% (95% credible interval (CrI): 60.7–84.4) on 22 December 2022 and 92.3% (95% CrI: 91.4–93.1) on 31 January 2023. A recent study by Liang et al. (2023) showed that the cumulative SARS-CoV-2 infection rate rose rapidly to 70% within three weeks after the ending of the zero-COVID policy in Macao. A study conducted in Guangzhou also revealed that the infection attack ratio reached to 80.7% (95% CrI: 72.2–86.8) at 30 days after easing the zero-COVID policy (Huang et al., 2023)

Indeed, there have been some studies discussing the impact of human factors on air pollution during and after the outbreak of the Coronavirus disease (e.g., Ma et al., 2022; Jiang et al., 2023; Song et al., 2023), but as mentioned earlier, only a few studies with in-depth exploration of the changes in VOCs and none dealing with ending the zero-Covid policy during Omicron variant infection period.

Our research primarily concentrates on the period dominated by COVID-19 Omicron variant, where they demonstrate notable differences from the early virus strains (i.e., original SARS-CoV-2 virus and Delta) in terms of geographical transmission, the scale of the infected population, and symptom manifestation.

The 7th announcement of 2022 issued by the National Health Commission of China states that, starting from January 8, 2023, the Class A infectious disease prevention and control measures specified in the Infectious Disease Prevention and Control Law of the People's Republic of China for COVID-19 will be lifted; COVID-19 will no longer be included in the quarantine infectious disease management stipulated by the Frontier Health and Quarantine Law of the People's Republic of China. This signifies a significant shift in China's pandemic control policy in comparison to the period preceding the issuance of the announcement. We believe that this change is worth exploring in terms of its impact on transportation and industrial production emissions. Essentially, this research serves to address the existing gap in the literature concerning the effects of the Omicron variant on VOCs and $PM_{2.5}$ pollution levels in Zhengzhou amidst policy fluctuations, specifically the end of zero-Covid policy.

Our research findings also confirm that traffic emissions remain the primary source of pollution in Zhengzhou, thus providing valuable insights for formulating control measures.

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Song, X., Zhang, D., Li, X., Lu, X., Wang, M., Zhang, B., Zhang, R.: Simultaneous observations of peroxyacetyl nitrate and ozone in Central China during static management of COVID-19: Regional transport and thermal decomposition, Atmospheric Research, Volume 294, 106958, https://doi.org/10.1016/j.atmosres.2023.106958, 2023.

Xinhua News Agency, The "new ten" to optimize the implementation of epidemic prevention and control is here, http://www.news.cn/politics/2022-12/07/c_1129189285.htm, 2022.

Major comments:

1) The major weakness of this work is the lack of innovation. The impacts of the Omicron outbreak on Chinese cities are already well-documented and extensive studies have been conducted to elucidate the role of the anthropogenic sector on air pollution during- and post-outbreak periods. The authors claimed that industrial and vehicular emissions are dominant sectors contributing to ambient VOC, which is quite clear in prior studies. Further, the changes in $PM_{2.5}$ and VOCs in response to the lockdown are broadly consistent with previous findings in Zhengzhou (even in Chinese literature). What is the innovation of this work and what are the new findings from this work that contribute to the air quality community?

Response: Again, we apologize for the lack of description of the rationale for our study and lack of in-depth analysis of our VOC results in our original draft. We have added the distribution of major flaws and the lack of innovation in the above comment, please see our point-by-point responses of [c]The major flaws and the lack of innovation.

The usage of SOAP should be revisited. The authors should be aware that SOAP is a very simple metric that provides limited information on SOA formation potential because SOA yield for individual VOCs in China may vary significantly in other countries due to the different levels of NOx and other oxidants. SOAP is generally adopted to reflect the SOA production potential based on bottom-up emission inventory (see Wu & Xie, ES&T), rather than using short-time ambient measurements. Therefore, I doubt the conclusion driven by the simple SOAP calculation. The authors should consider using F0AM and PBM-MCM for examining SOA production changes rather than SOAP.

Response: Thank you very much for your valuable advice. After carefully reading the literature you recommended, we found that the analysis conclusions about SOAP in Wu & Xie 's research have some similarities with ours (Wu et al., 2018). For example, Wu & Xie 's research found that aromatics contribute the most to SOAP, followed by alkanes and alkenes. Similarly, the results calculated using the toluene weighted mass contributions method (Derwent et al., 2010) also indicate that aromatics contribute the most to SOAP, followed by alkanes and alkenes. The toluene weighted mass contributions method has been widely used in calculating SOAP based on observed VOCs (Zhang et al., 2017; Hui et al., 2019; Li et al., 2020). Therefore, this method also has a certain representativeness. Of course, as you said, this is not the most appropriate method, and using F0AM and PBM-MCM for examining SOA production changes is a very good suggestion. However, due to the limitations of our related technologies, we are unable to use F0AM or PBM-MCM for examining SOA production changes. This is a very regrettable thing. Your suggestion has pointed out a very good direction for our future research.

On the other hand, PBM-MCM can indeed effectively simulate atmospheric chemical processes in the troposphere under certain circumstances. Taking MCMv3.2 as an example, it includes 5900 species of reactants and 16500 chemical reactions. During the modeling process, a large number of model parameters need to be set, and it is influenced by various environmental variables such as temperature, atmospheric pressure, relative humidity, boundary layer height (Lam et al., 2013), among others. The–results may have significant errors compared to the true values. Furthermore, this model is often used to analyze the sources of atmospheric O_3 (Xie et al., 2021).

The issues faced when applying the F0AM model are similar as well. For example, the observed photodissociation frequency (J value) needs to be input. The photodissociation frequency controls the generation of free radicals and the lifetimes of many compounds. Due to the various influencing factors, the accurate simulation of J values is challenging. A major shortcoming of the modeling approach is the lack of explicit representation of transport processes (entrainment, dilution, etc.), which has several practical consequences. First, primary emissions like NO_x and hydrocarbons must be constrained or otherwise re-supplied to compensate for chemical loss. Emissions can also be parameterized explicitly but require knowledge of the boundary layer depth and assumed instantaneous mixing. Second, a generic "physical loss" lifetime of 6–48 h is often assigned to all species to mitigate build-up of long-lived oxidation products over multiple days of integration. Model users must be aware of the limitations imposed by these choices (Wolfe et al., 2016).

Even though the SOAP calculation process based on a coefficient of individual VOC species developed by Derwent et al. (2010) certainly has errors, it is our belief that SOA production obtained from F0AM and PBM-MCM models exhibited as many uncertainties as a simple Derwent's SOAP approach.

The importance of SOA to atmospheric problems is well known. Previous studies have used SOAP calculations to investigate the contribution of atmospheric VOCs to $PM_{2.5}$ production, demonstrating that contribution of different sources to the formation of SOA. (Shi et al., 2015; Liu et al., 2022; Liang et al., 2023). In our paper, SOAP values were determined to reflect the impact of the end of China's zero-Covid policy. But we will continue to work hard, hoping to include the analysis of F0AM and PBM-MCM in our future research.

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Zhang, Z., Wang, H., Chen, D.: Emission characteristics of volatile organic compounds and their secondary organic aerosol formation potentials from a petroleum refinery in Pearl River Delta, China, Science of The Total Environment, 584–585, 1162-1174, https://doi.org/10.1016/j.scitotenv.2017.01.179, 2017.

3) The captions of the results section are meaningless. "Pollution characteristics" and "Source appointment" is not clear to the readers and should be rewritten for clarification.

Response: We have modified “Pollution characteristics” to “Overview of variation in pollutants and meteorological parameters”, and “Source appointment” to “Source Analysis of VOCs”.

4) The writing of this paper is in need of much attention. Specifically, the writing suffers from a series of fundamental issues, including a lack of

clear organization, pervasive grammatical, and stylistic errors. I suggest the authors carefully read through the manuscript and rephrase the results section. There is substantial awkward phrasing throughout the paper which is confusing and misleading to the readers.

Response: We apologize for the grammatical and stylistic errors in the manuscript, and unclear statement which certainly confuses readers. We have addressed your comments in serval parts with superscript [a, b] above.

We will undertake extensive revisions and proofreading to enhance the clarity and coherence of the manuscript. This will ensure that the article is free from grammatical errors and stylistic issues, making it easier for readers to understand.

Minor comments:

1) The SOA formation potential is called "SOAP" rather than "SOAFP". The author should correct this abbreviation.

Response: After thorough examination of the literature, we found both usages in circulation. However, in the revised text, we shall adopt your suggested term of SOAP, as demonstrated in our replies to reviewers' comments.