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Influence of COVID-19 lockdown overlapping Chinese Spring Festival on household PM$_{2.5}$ in rural Chinese homes

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During the 2019 novel coronavirus (COVID-19) pandemic, many countries took strong lockdown policy to reduce disease spreading, resulting in mitigating the ambient air pollution due to less traffic and industrial emissions. However, limited studies focused on the household air pollution especially in rural area, the potential risk induced by indoor air pollution exposure was unknown during this period. This field study continuously measured real-time PM$_{2.5}$ levels in kitchen, living room, and outdoor in the normal days (Period-1) and the days of COVID-19 lockdown overlapping the Chinese Spring Festival (Period-2) in rural homes in China. The average daily PM$_{2.5}$ concentrations increased by 17.4 and 5.1 mg/m$^3$ in kitchen and living room during Period-2, respectively, which may be due to more fuel consumption for cooking and heating caused by larger family sizes than those during the normal days. The ambient PM$_{2.5}$ concentration in rural areas in Period-2 decreased by 6.7 mg/m$^3$ compared to the Period-1, less than the drop in urban areas (26.8 mg/m$^3$). An increase of mass fraction of very fine particles in ambient air was observed during lockdown overlapping annual festival days, which could be explained by the residential solid fuel burning. Due to higher indoor air pollution level and longer time spent in indoor environments, daily personal exposure to PM$_{2.5}$ was 134 ± 40 mg/m$^3$ in Period-2, which was significantly higher than that during in Period-1 (126 ± 27 mg/m$^3$, $p < 0.05$). The increase of personal PM$_{2.5}$ exposure during Period-2 could potentially have negative impact on human health, indicating further...
investigations should be performed to estimate the health impact of global COVID-19 lockdown on community, especially in rural homes using solid fuels as the routine fuels.

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1. Introduction

Household air pollution (HAP, including indoor air pollution and outdoor air pollution) in rural homes associated with solid fuel use are severe due to the incomplete combustion of solid fuels, which is catching raising concern (Baumgartner et al., 2011; Tao et al., 2018; Du et al., 2018; Wang et al., 2017, 2018). The severe household air pollution could result in negative health outcome, and nearly 2.31 million premature deaths were caused by household air pollution (HAP) globally, accounted for nearly 34.6% of the PM2.5-related premature deaths (GBD, 2020). In China, it was estimated that the residential solid fuel use contributed 43% to the total premature deaths associated with PM2.5 (particulates with the aerodynamic size < 2.5 μm) exposure and caused more than 0.52 million premature deaths per year in China (Zhao et al., 2018). Given the populations relying on solid fuels for cooking and space heating were about 2.8 billion and most of them lived in developing countries (e.g. China and India) (Bonjour et al., 2013), the effect of household air pollution on human health in rural areas was non-negligible currently and in foreseeable future.

COVID-19 was a wicked coronavirus broken out at the beginning of 2020 and has lasted more than one year. It caused more than 1,754,547 deaths and 79,231,893 cases confirmed around the world (Millán-Oñate et al., 2020; WHO, 2020) till the paper written. China has enacted emergency lockdown policy to slow down the spread of the disease from late January 2020 (Tian et al., 2020). The sharp decrease of vehicle and industry emissions and human activities caused by lockdown resulted in significantly better ambient air quality in cities (Sicard et al., 2020). It was found that most air pollutants such as PM2.5, CO, SO2, and NO2 decreased accordingly after the lockdown (Li et al., 2020; NASA, 2020; Sicard et al., 2020). Although there were already numerous studies focused on the effect of the lockdown on the ambient air pollution, there is limited studies focused on the changes of HAP in rural areas of China associated with the COVID-19 lockdown (Shen et al., 2021).

As a traditional culture in China, hundreds of millions of young people usually travelled back to rural hometowns to spend the Spring Festival, the biggest migration in the world named “Spring Festival travel” (Fan et al., 2020; Pan, 2021). Generally, if no COVID-19 lockdown, the youths would leave rural homes and return to cities for work within about 2 days after the Spring Festival, but failed in this year due to the lockdown across the whole country, which means the elders in rural households would live with the youths from cities in the period of COVID-19 lockdown overlapping the Chinese Spring Festival. The bigger rural family sizes in this period could result in more fuels needed for food cooking and/or space heating. What’s more, people spent more time in indoor environments under the strict lockdown. Given the fact that the Chinese young people need to live with the elders in the rural homes in this special period in the early 2020, the HAP in rural areas might be different from urban areas, while limited studies focused on this impact in HAP in rural areas, especially for indoor air pollution (Du and Wang, 2020). A field measurement was conducted in rural homes in Hunan Province, southern China to clarify this hypothesis. The objectives of this study are 1) to measure the HAP in rural homes burning solid fuels based on real-time sensors; 2) to assess the impact of COVID-19 lockdown overlapping the Chinese Spring Festival on HAP and personal exposure in rural homes and on size distribution of ambient particles.

2. Methods

2.1. Household PM$_{2.5}$ measurement

We recruited 23 rural households in which the residents were willing to participate in this study to measure the household air pollution of their homes in Taojiang county (28°13′-28°41′E, 111°36′-112°19′N), Yiyang City in Hunan Province, southern China. The location of the study site was provided in Fig. S1. In this area, solid fuels, such as wood, were commonly used for cooking. In some rich households, liquefied petroleum gas (LPG) was used for daily cooking. Although the need for space heating in this area was not as strong as that in northern China, residents also burnt solid fuels such as wood and wood charcoal or used electricity in cold morning and night for heating. The pictures of typical cooking and heating stoves used in this area were presented in Fig. S2.

The real-time PM$_{2.5}$ monitors were paired placed in kitchen, living room and outdoor (yard) of each recruited household. The PM$_{2.5}$ monitors used in the present study were the same with previous studies (Qiu et al., 2019; Chen et al., 2020) and the data was recorded with a 5-s interval. Before the field campaign, all the samplers were calibrated for at least 15 days against the measurements of a particulate monitor (model 5030 synchronized hybrid ambient real-time particulate monitor, Thermo Scientific). The samplers were placed at the height of 1.5 m and 1.0 m away from stoves and walls followed other household air measurements (Du et al., 2017). A questionnaire derived from a face-to-face interview recorded the fuel type for cooking and heating activities, fuel consumption, how many residents in the households, time spent in different microenvironments (kitchen, living room, and outdoor), and gender.

The measurement was from January 14 to January 30 which covered the days before lockdown, COVID-19 lockdown overlapping the Spring Festival (January 23 to 30), a total of 368 household/day data was collected for kitchen, living room and outdoor air, respectively. As the COVID-19 lockdown took place in January 23 in the study area, the result from January 14 to January 22 represented the situation of “before lockdown” (defined as Period-1), the result from January 23 to January 30 represented the situation of “COVID-19 lockdown overlapping the Chinese Spring Festival” (defined as Period-2).

After the lockdown policy being announced, we revisited the households in January 24 to update the information including fuel type for cooking and heating activities, fuel consumption, how many residents in the households, time spent in different microenvironments (kitchen, living room, and outdoor), and gender and other information.

2.2. Size-segregated particles collected in ambient air in rural area

To investigate the size distribution of particles in the study period, a nine stage Micro-Orifice Uniform Deposit Impactor (28.3 L/min, Anderson, Thermo Electron Corporation, USA) and 80 mm quartz filters were adopted. The sampler was placed at the
roof of a third-floor building in the study village at a height about 10 m. The cutoff points of the samplers were 0.4, 0.7, 1.1, 2.1, 3.3, 4.7, 5.8 and 9.0 μm, respectively. The flow rate of the sampler was calibrated before and after each sampling cycle. We collected each set of samples based on a 2-day duration and the sampling started from January 15 to February 2, which also covered the days before lockdown and COVID-19 lockdown overlapping the Chinese Spring Festival. Finally, a total of 9 sets of size-segregated samples were obtained.

2.3. Method to estimate the daily PM$_{2.5}$ exposure

The daily personal exposure to PM$_{2.5}$ was calculated based on a time-weighted method (Ott, 1982; Du et al., 2017), this method was commonly used when no directly measured personal exposure data was available (Chen et al., 2020) and the equation was given below:

$$\text{Exposure} = \frac{\sum_{i=m}^{n} C_i \times T_i}{1440}$$  \hspace{1cm} (1)

where $C_i$ is the PM$_{2.5}$ concentration in microenvironment $i$ (kitchen, living room, and outdoor) and $T_i$ was the corresponding time (minutes) the residents spent in microenvironment $i$. As the PM$_{2.5}$ in bedroom was not measured in this study, the time spent in bedroom was combined with the time spent in living room in the calculation.

2.4. Data analysis

The hourly and daily household PM$_{2.5}$ concentrations were calculated based on the data recorded with a 5-s interval. SPSS 21.0 (IBM Corporation, Armonk, NY, USA) was used for statistical analysis with a significance level of 0.05. Non-parameter Spearman correlation and Kolmogorov-Smirnov and one-way Anova methods were applied.

3. Results and discussion

3.1. The household PM$_{2.5}$ pollution in the rural homes

During the whole campaign, the PM$_{2.5}$ concentrations in kitchen, living room, and yard were 162 ± 70, 129 ± 42, 105 ± 26 μg/m$^3$, one-way Anova result showed the differences among these three microenvironments are significant ($p < 0.05$) following a trend of kitchen > living room > outdoor. This trend was similar to the results of other studies in rural areas, mainly due to the strong indoor emissions from cooking and space heating (Du et al., 2018).

The PM$_{2.5}$ concentrations in the homes of the study area are apparently higher than the standard for ambient air set by WHO, which is 25 μg/m$^3$, indicating the potentially severe health impact of PM$_{2.5}$ pollution on rural residents (WHO, 2019). Fig. 1 showed the PM$_{2.5}$ concentrations and characteristics of measured families in different periods. The average daily PM$_{2.5}$ concentration in kitchen was 169 ± 80 μg/m$^3$ in Period-2, increased by 17.4 μg/m$^3$ compared with the days of Period-1, and the difference was statistically significant ($p < 0.05$). Similarly, for living room, an increase of the average daily PM$_{2.5}$ concentration was observed (130 ± 48 μg/m$^3$) compared to that (125 ± 33 μg/m$^3$) of Period-1 (Fig. 1A). This result could be explained by more pollutant emissions caused by larger fuel consumption in these households. As Fig. 1B showed, the family sizes increased by 83% ($p < 0.05$) during Period-2 compared to the Period-1. It is easy to understand the fact that when the family sizes increased, more fuels were needed for cooking and heating (Yip et al., 2017). In this study, the daily fuel consumption was 28.7 ± 13.4 kg/day per household during Period-2, higher than the days of Period-1 (23.5 ± 11.0 kg/day per household, $p > 0.05$). Otherwise, the daily average outdoor PM$_{2.5}$ concentration decreased by 6.7 μg/m$^3$ during Period-2, lower than the days of Period-1 ($p < 0.05$), might partly explained by less traffic and industrial emissions in the near areas, which would be discussed afterwards.

Fig. 2 showed the continuous measured PM$_{2.5}$ concentrations (from January 14 to January 30) in kitchen, living room, and outdoor air in a typical household. It could be easily observed that apparent increase of PM$_{2.5}$ in kitchen and living room after the announcement of lockdown. And, a decrease of outdoor PM$_{2.5}$ was also observed. It was also found that a low HAP from Jan. 28 to 29, which could be explained by less heating fuel used in this day, which was reported by the local residents. Noting that this measurement was in southern China without strong need for space heating, higher indoor PM$_{2.5}$ concentrations might be observed in northern homes of China where space heating was needed in this period as large fuel consumption was needed (Tao et al., 2018).

3.2. Compared with ambient air pollutants in urban area

The 1-h resolution ambient PM$_{2.5}$ concentrations data in the urban areas of Yiyang city released by the China National Environmental Monitoring Center (CNEMC, 2020) as well as NO$_2$, a tracer of traffic and industrial emissions, were collected for analysis (Sharma et al., 2020). Fig. 3A showed the temporal variations of ambient PM$_{2.5}$ and NO$_2$ in urban areas from January 14 to January 30, the decreases of PM$_{2.5}$ and NO$_2$ were observed in Period-2 compared to the Period-1, which were similar to the result in rural areas. The daily average concentrations of ambient PM$_{2.5}$ and NO$_2$ decreased by 26.8 and 11.2 μg/m$^3$ ($p < 0.05$), respectively, in Period-2 compared to the days of Period-1 (see Fig. 3B). The similar results were also found in previous studies (Sharma et al., 2020; Pierre et al., 2020). The most possible reason was the huge drop in traffic and industrial emissions in urban areas. As mentioned above, the outdoor PM$_{2.5}$ in rural area decreased by 6.7 μg/m$^3$ in Period-2 compared to the days of Period-1, this drop was less than that in the urban areas (26.8 μg/m$^3$). The most possible reason for the result that the rural areas owned a less reduction of outdoor PM$_{2.5}$ was the increase of residential emissions from the cooking and heating in rural households could provide an offset of PM$_{2.5}$ reduction (Pierre et al., 2020). Fig. 3C showed a positive correlation of ambient PM$_{2.5}$ in urban area and outdoor PM$_{2.5}$ in rural area ($p < 0.05$). The result also showed the variances of outdoor PM$_{2.5}$ in rural areas could be explained only 35% by urban PM$_{2.5}$, again indicating the rural area had a different mechanism of outdoor PM$_{2.5}$ drop during Period-2 compared to the urban area.

3.3. The size distribution of ambient particles of rural area in Period-1 and 2

Size-segregated ambient particles were also collected in this study. It would be interesting to investigate the size distributions of ambient particles in the study site during Period-1 and Period-2. Fig. 4 presented the result of size distributions of particles collected at the roof of a local building, which could reflect the characteristic of the ambient particles. It could be clearly found that the mass fraction of very fine particles (<0.4, 0.4–0.7, and 0.7–1.1 μm) increased in Period-2 when compared with the Period-1, in which the difference of PM$_{2.1-3.3}$ was significant ($p < 0.05$). While, the mass fraction of particles with a diameter >11 μm decreased in Period-2 when compared with the Period-1, in which the difference of PM$_{2.1-3.3}$ was significant ($p < 0.05$). This
Fig. 1. The PM$_{2.5}$ concentrations and characteristics of measured families before and after the lockdown. A) the daily average PM$_{2.5}$ concentrations in kitchen, living room and ambient air of the rural households; B) the family size, fuel consumption and average time the local residents spent in outdoor. * represented the difference was significant at the level of 0.05.

Fig. 2. Continuous measured PM$_{2.5}$ concentrations in kitchen, living room and ambient with 1-h resolution in a typical household.

Fig. 3. The real time PM$_{2.5}$ and NO$_2$ concentrations in urban air (1-h resolution), all data is publicly released online (http://106.37.208.233:20035/) by the China National Environmental Monitoring Center (CNEMC) within 1 h after the direct sampling (A); the average concentrations of urban PM$_{2.5}$ and NO$_2$ in Period-1 and Period-2 (B); the correlation between ambient PM$_{2.5}$ in urban and outdoor PM$_{2.5}$ in rural areas (C).
result could fit well with the result mentioned above, which could be explained by the potential source difference in Period-2 compared with the Period-1. During Period-2, many industrial productions were also stopped in the urban areas, and motor vehicles also decreased on the roads, the ambient air pollution in the study area was dominantly derived from solid fuel combustion. It was reported particles with diameter <2.1 μm could contributed more than 70% to the total PMs emission from the solid fuels burning in residential stoves, the increase of mass fraction of very fine particles to total PMs could result from the local biomass combustion (Chen et al., 2005; Shen et al., 2012, 2017). Fan et al. (2020b) found a decline of PM$_{2.5}$/PM$_{10}$ at city scale, which suggested a different change of mass fraction of fine particles from the result of this study, which was conducted in rural area.

3.4. Impact of COVID-19 lockdown overlapping the Spring Festival on PM$_{2.5}$ exposure

Although the outdoor PM$_{2.5}$ in rural areas decreased slightly during the special Spring Festival overlapping COVID-19 lockdown, the personal exposure to PM$_{2.5}$ of local residents would be higher considering the local residents spent more time in kitchen and living room and higher indoor air pollution. Given the air pollution itself was associated with non-communicable diseases such as respiratory allergies and lung cancer (Cohen et al., 2017), the COVID-19 lockdown overlapping the annual festival days might increase the health risk due to higher PM$_{2.5}$ exposure caused by higher indoor air pollution and longer time spent in indoor. In this study, the daily personal exposure to PM$_{2.5}$ calculated based on the concentrations in different microenvironments and corresponding time spent in these microenvironments was $134 \pm 40 \, \text{μg/m}^3$ in Period-2, higher than the daily PM$_{2.5}$ exposure in the days of Period-1 ($126 \pm 27 \, \text{μg/m}^3$, $p < 0.05$). For male, daily PM$_{2.5}$ exposures were $125 \pm 25 \, \text{μg/m}^3$ and $132 \pm 39 \, \text{μg/m}^3$, respectively, in Period-1 and Period-2. For female, daily PM$_{2.5}$ exposures were $128 \pm 28 \, \text{μg/m}^3$ and $135 \pm 42 \, \text{μg/m}^3$, respectively, in Period-1 and Period-2 ($p < 0.05$). Similarly, a model study estimated that during lockdown, the national ambient PM$_{2.5}$ could decrease by 16.7 μg/m$^3$, but the overall population exposure to PM$_{2.5}$ could increase 5.7 μg/m$^3$ (Shen et al., 2021). Till now, no available study based on field measurement on the PM$_{2.5}$ exposure associated with HAP caused by the lockdown except for this study. The PM$_{2.5}$ exposure increase after the lockdown indicated the importance of HAP in China, especially in rural areas.

Higher PM$_{2.5}$ exposure during the Period-2 indicated the potential negative impact on human health, indicating further investigations should be performed to estimate the health impact of global COVID-19 lockdown on community, especially in rural homes using solid fuels as the routine fuels. It was hard to investigate the long-term effect of PM$_{2.5}$ exposure increase in the annual festival days overlapping COVID-19 lockdown. For example, we could not estimate the PM$_{2.5}$-associated premature deaths because it was estimated based on the whole life, not a short period (Yun et al., 2020). While, some short-term effect such as asthma, blood pressure increase may be caused by the increase of PM$_{2.5}$ exposure in a relative short time considering the lockdown in rural China lasted for more than one month (Wang et al., 2018; Williams et al., 2019; Chen et al., 2020).

3.5. Implications and limitations

After the strong action taken by Chinese government, the residents were asked to stay at home and stop going out for work or travel. The implementation of stringent lockdown resulted in less traffic and industrial emissions, thus dropped in ambient air pollutants (PM$_{2.5}$ and NO$_2$) were observed in urban areas. While in rural areas, the household air pollution might be higher due to the larger family sizes and fuel consumption. To our best knowledge, this study is the first field study which focused on the household air pollution in rural homes during the special Spring Festival overlapping COVID-19 lockdown, giving a special insight on the potential impact of lockdown overlapping the annual festival days on household air pollution. Nowadays, COVID-19 is still very fiendish all over the world and in another pandemic and the confirmed cases increased quickly every day. Many countries might have rigorous lockdown policy at this stage. In our view, the household air pollution should get more concerns, especially in rural homes using solid fuels. Future studies, both experimental and epidemiological studies should be performed to assess the impact of indoor air pollution on population health during COVID-19 lockdown.

In previous studies, COVID-19 lockdown was considered as a positive benefit for human to a certain extent due to the reduction of ambient air pollution including NO$_2$ and PM$_{2.5}$ (Dutheil et al., 2020; Sharma et al., 2020; Pierre et al., 2020), but the effect might be negative in rural areas according to the result of our study since the rural residents spent most time in indoor. It was believed that the indoor air pollution was important for rural residents, especially in developing countries which rely on solid fuels for cooking and heating and still in the lockdown. For example, after the lockdown, millions of Indians walked back to rural homes (CNN, 2020), the indoor air pollution might also be higher as the larger solid fuel consumption, similar to China. Based on the result of this study, we believed the situation of indoor air pollution is similar, if not the same, in other developing countries. The result of this study would help researchers to focus on the environmental impacts of COVID-19 lockdown and also the policy makers to prevent human health based on the fact that COVID-19 lockdown would be happening in some countries.

There are several limitations should be noted. First, the sample size is relatively small although the data is with high resolution in time due to the difficulty for sampling and high cost in the field study. And, because the field study was only conducted in Hunan Province, we cannot estimate the impact of COVID-19 lockdown overlapping the Spring Festival on household air quality accurately since the large spatial difference in China (Ren et al., 2020). From Du et al. (2018) study, the indoor air pollution in northern China was much higher than that in southern China due to strong need for space heating. As the COVID-19 lockdown was started at January 23 when most northern areas were still in the heating season, the indoor air pollution would cause severer health outcome on rural
residents during this period. In some warm areas in southern China, households using clean fuels such as LPG and electricity, the situation would be better (Du et al., 2018). Second, we failed to extend the landscape which covered the recovery period after COVID-19 lockdown, which might be powerful and we could capture and avoid the impact of the Spring Festival and COVID-19 lockdown. We hope future studies could further focus on the impact of lockdown on household air pollution and personal exposure to air pollutants.

4. Conclusions

In this study, we found PM$_{2.5}$ concentrations increased by 11.5% and 4.1%, respectively, in kitchen and living room in the annual festival days overlapping COVID-19 lockdown compared to the normal days, mainly owing to larger family sizes and fuel consumption needed for cooking and heating in rural homes. The outdoor PM$_{2.5}$ in rural area decreased by 6.7 µg m$^{-3}$ in the annual festival days overlapping COVID-19 lockdown, less than the reduction of 26.8 µg m$^{-3}$ on festival days overlapping COVID-19 lockdown, which might be powerful and we could capture and avoid the impact of the Spring Festival and COVID-19 lockdown.

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Baumgartner, J., Schauer, J.J., Ezzati, M., Lu, L., Cheng, C., Patz, J., Bautista, L.E., 2011. Prediction of epidemic spread of the 2019 novel coronavirus driven by spring festival transportation in China: a population-based study. Int. J. Environ. Res. Public Health 17 (5).

Sharma, S., Zhang, M., Anshika, Gao, J., Zhang, H., Kota, S., 2020. Effect of restricted movement during the lockdown of COVID-19 outbreak: a spatiotemporal investigation at Chinese city-level. Int. J. Environ. Res. Public Health 17 (11).

Global Burden of Disease (GBD). [https://vizhub.healthdata.org/gbd-compare/]. Accessed Jan. 2021.

References

Baumgartner, J., Schauer, J.J., Ezzati, M., Lu, L., Cheng, C., Patz, J., Bautista, L.E., 2011. Patterns and predictors of personal exposure to indoor air pollution from biomass combustion among women and children in rural China. Indoor Air 21, 479–488.

Bonjour, S., Adair-Rohani, H., Wolf, J., Bruce, N., Mehta, S., Prüss-Ustun, A., Lalloo, M., Rehfuess, E., Mishra, V., Smith, K., 2013. Solid fuel use for household cooking: country and regional estimates for 1980–2010. Environ. Health Perspect. 121, 764–790.

Chen, Y.J., Chen, G.Y., Bi, X.H., Feng, Y.L., Mai, B.X., Fu, J.M., 2005. Emission factors for carbonaceous particles and polycyclic aromatic hydrocarbons from residential coal combustion in China. Environ. Sci. Technol. 39, 1861–1867.

Chen, Y., Fei, J., Sun, Z., Shen, C., Du, W., Zang, L., Yang, L., Wang, Y., Wu, R., Chen, A., Zhao, M., 2020. Household air pollution from cooking and heating and its impacts on blood pressure in residents living in rural cave dwellings in Loess Plateau of China. Environ. Sci. Polilt. Res. 27, 36677–36687.

CNEN-SciEcoDir-2020-033. [https://doi.org/10.37.2018.233.20313.accessed 2020.04.29]

Cnn. Chaotic Scenes as Migrant Workers Try to Leave Major Cities in India. https://edition.cnn.com/videos/world/2020/03/29/coronavirus-india-migrant-workers-leave-orig-bks.cnn.accessed 2020.04.29.

Dong, Z., Zhang, Y., Zhang, L., Ye, R., Li, Zhi, Guan, W., Wang, B., 2020. Contribution of temperature increase to restrain the transmission of COVID-19. Innovation 2, 100071.

Dong, Z., Zhang, Y., Zhang, L., Ye, R., Li, Zhi, Guan, W., Wang, B., 2020. Contribution of temperature increase to restrain the transmission of COVID-19. Innovation 2, 100071.

Fan, C., Liu, L., Guo, W., Song, A., Ye, C., Jili, M., Ren, M., Xu, P., Long, H., Wang, Y., 2020. Prediction of epidemic spread of the 2019 novel coronavirus driven by spring festival transportation in China: a population-based study. Int. J. Environ. Res. Public Health 17 (5).

Fan, C., Zhang, Q., Yang, C., Li, H., Zhan, M., 2020b. How did distribution patterns of particulate matter air pollution change (PM$_{2.5}$ and PM$_{10}$) change in China during the COVID-19 outbreak: a spatiotemporal investigation at Chinese city-level. Int. J. Environ. Res. Public Health 17 (11).

Global Burden of Disease (GBD). [https://vizhub.healthdata.org/gbd-compare/]. Accessed Jan. 2021.

Li, L., Li, Q., Huang, L., Wang, Q., Zhu, A., Xu, J., Liu, Z., Li, H., Sh., Li, L., Li, R., Azari, M., Wang, Y., Zhang, X., Li, Z., Zhu, Y., Zhang, K., Xue, S., Oo, M., Zhang, D., Chan, A., 2020. Air quality changes during the COVID-19 lockdown over the Yangtze River Delta Region: An insight into the impact of human activity pattern changes on air pollution variation. Sci. Total Environ. 735, 139542.

Pan, X.F., 2021. Investigating college students’ choice of train trips for homeschooling during the Spring Festival travel rush in China: results from a stated preference approach. Transp. Lett. 13, 36–44.

Pierre, S., Alessandra, D., Evgenia, A., Feng, Z., Xu, X., Elena, P., Jose, J., Vicent, C., 2020. Amplified ozone pollution in cities during the COVID-19 lockdown. Sci. Total Environ. 735, 139542.

Qu, Y., Tao, S., Yun, X., Du, W., Shen, G., Lu, C., Yu, X., Cheng, H., Ma, J., Xue, B., Tao, J., Dai, J., Q., 2019b. Indoor PM$_{2.5}$ profiling with a novel side-scatter indoor lidar. Environ. Sci. Technol. Lett. 6, 612–616.

Ren, M., Pei, R., Jiangtulu, B., Chen, J., Xue, X., Shen, G., Yuan, X., Li, K., Lan, C., Chen, Z., Chen, X., Wang, Y., Xia, J., Li, Z., Rashid, A., Prapatmonthon, T., Zhao, X., Dong, Z., Zhang, Y., Zhang, L., Li, Z., L., Zhi, Guan, W., Wang, B., 2020. Contribution of temperature increase to restrain the transmission of COVID-19. Innovation 2, 100071.

Sharma, S., Zhang, M., Anshika, Gao, J., Zhang, H., Kota, S., 2020. Effect of restricted movements during COVID-19 on air quality in India. Sci. Total Environ. 728, 119878.

Shen, G.F., Wei, S.Y., Wei, W., Zhang, Y.Y., Min, Y.J., Wang, B., Wang, R., Chen, H.Z., Huang, Y., Yang, Y.F., Wang, W., Wang, X.J., Tao, S., 2012. Emission factors, size distributions, and emission inventories of carbonaceous particulate matter from residential wood combustion in rural China. Environ. Sci. Technol. 46, 4207–4214.

Shen, G.F., Gaddam, C.K., Eberswyler, S.M., Wol, R.L.V., Williams, C., Faircloth, J.W., Jetter, J.J., Hays, M.D., 2017. A laboratory comparison of emission factors, number size distributions, and morphology of ultrafine particles from 11 different household cookstove-fuel systems. Environ. Sci. Technol. 51, 6522–6532.

Shen, H., Shen, G., Chen, Y., Russell, A., Hu, Y., Duan, X., Meng, W., Xu, Y., Yun, X., Luyu, B., Zhao, S., Hakanma, A., Tao, S., Smith, K., 2021. Increase in air pollution exposure among the Chinese population during the national quarantine in 2020. Nat. Human Behav. 5, 446.

Tao, S., Ru, M., Du, W., Zhu, X., Zhong, Q., Li, B., Shen, G., Pan, X., Meng, W., Chen, Y., Shen, H., Lin, N., Su, S., Zuo, H., Huang, T., Xu, Y., Yun, X., Liu, J., Wang, X., Liu, W., Cheng, H., Zhu, D., 2018. Quantifying the rural residential energy transition in China from 1992 to 2012 through a representative national survey. Nat. Energy 3, 567–573.

Tian, H., Liu, Y., Li, Y., Wu, C., Chen, B., Kraemer, M., Li, B., Cai, J., Xu, B., Yang, Q., Wang, B., Yang, P., Cui, Y., Song, Y., Zheng, P., Wang, Q., Bjornstad, O., Yang, R., Grenfell, B., Pybus, O., Dye, C., 2020. An investigation of transmission control
measures during the first 50 days of the COVID-19 epidemic in China. Sci 368, 638–642.
Wang, B., Yan, L., Huo, W., Lu, Q., Cheng, Z., Zhang, J., Li, Z., 2017. Rare earth elements and hypertension risk among housewives: a pilot study in Shanxi Province, China. Environ. Pollut. 220, 837–842.
Wang, B., Zhu, Y., Pang, Y., Xie, J., Hao, Y., Yan, H., Li, Z., Ye, R., 2018. Indoor air pollution affects hypertension risk in rural women in Northern China by interfering with the uptake of metal elements: a preliminary cross-sectional study. Environ. Pollut. 240, 267–272.
Williams, A.M., Phaneuf, D.J., Barrett, M.A., Su, J.G., 2019. Short-term impact of PM2.5 on contemporaneous asthma medication use: behavior and the value of pollution reductions. P Natl. Acad. Sci. USA 116, 5246–5253.
World Health Organization (WHO). https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports accessed 2021.01. 03.
World Health Organization (WHO), 2019. Mortality from Household Air Pollution, p. 422. https://www.who.int/gho/phe/indoor_air_pollution/burden/en/.
Yip, F., Christensen, B., Sircar, K., Naeher, L., Bruce, N., Pennise, D., Lozier, M., Pilishvili, T., Farrar, J.L., Stanistreet, D., Nyagol, R., Muoki, J., de Beer, L., Sage, M., Kapil, V., 2017. Assessment of traditional and improved stove use on household air pollution and personal exposures in rural western Kenya. Environ. Int. 99, 185–191.
Yun, X., Shen, G.F., Shen, H.Z., Meng, W.J., Chen, Y.L., Xu, H.R., Ren, Y., Zhong, Q.R., Du, W., Ma, J.M., Cheng, H.F., Wang, X.L., Liu, J.F., Wang, X.J., Li, B.G., Hu, J.Y., Wan, Y., Tao, S., 2020. Residential solid fuel emissions contribute significantly to air pollution and associated health impacts in China. Sci. Adv. 6, 44.
Zhao, B., Zheng, H., Wang, S., Smith, K.R., Lu, X., Aunan, K., Gu, Y., Wang, Y., Ding, D., Xing, J., Fu, X., Yang, X., Liou, K.N., Hao, J., 2018. Change in household fuels dominates the decrease in PM2.5 exposure and premature mortality in China in 2005-2015. P. Natl. Acad. Sci. USA 115, 12401–12406.
Sicard, P., De Marco, A., Agathokleous, E., Feng, Z.Z., Xu, X.B., Paoletti, E., Rodriguez, J.J.D., Calatayud, V., 2020. Amplified ozone pollution in cities during the COVID-19 lockdown. Science of the Total Environment 735.