Consequences of pre and post confinement on the atmospheric air pollutants during spread of COVID-19 in India

K Patel and A K Singh

1Department of Physics, SRM Institute of Science and Technology, Delhi-NCR Campus, Modinagar, Ghaziabad, Uttar Pradesh 201204, India
2Atmospheric Research Laboratory, Department of Physics, Banaras Hindu University, Varanasi, Uttar Pradesh 221005, India

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Abstract: COVID-19, a severe respiratory syndrome, was diagnosed in Wuhan, China, and in the last week of January 2020, it was reported in India. The drastic speed of spreading of COVID-19 imposed a total lockdown in India for the first time in four stages. This leads to restrictions on transport, industries, coal-based power plants, etc. During these stages of lockdown, a detailed analysis was done to study the effect of confinement on various air pollutants, PM$_{10}$, PM$_{2.5}$, SO$_2$, CO, NH$_3$, and NO$_x$ (NO, NO$_2$) over the thirteen different stations situated at different states in India. The data were compared with pre-confinement duration at different locations in India. During confinement, the air pollutants showed less value when compared with the pre-confinement stage alarming everyone and also the Indian government to bring up rules and regulations for better air quality index so that such pandemics should be reduced.

Keywords: COVID-19; Lockdown; Air quality index; Respiratory syndrome

1. Introduction

A troublesome pandemic due to SARS-COV-2 was recognized firstly in Wuhan, China, in December 2019 [1, 2]. It became a worldwide pandemic situation and has affected about 63,072,905 people. Out of this number, 43,546,236 were recovered and total deaths were 1,465,186 as reported by world meter in the last 2–3 days of November 2020. WHO declared it a worldwide deadly disease on March 11, 2020 [3]. Earlier it has been observed that the COVID-19 virus is unable to stay alive at superior temperature because its lipid layer breaks at elevated temperatures and is facilitated by the cold and dry atmosphere [4].

With the first case found in India which was on January 30, 2020, an increasing number of cases due to epidemic Covid-19 were identified and a time was reached when a suspected community of about 2000 people was reported and was suspected to have many positive cases of Covid-19. Later on, a big hike was there in the cases and a shutdown was implemented in India in four rounds. The first round of lockdown is from 03/25/2020 to 04/14/2020, the second round from 04/15/2020 to 05/03/2020, the third round is from 05/04/2020 to 05/17/2020, and last the fourth round is from 05/18/2020 to 05/31/2020 [3]. Due to the measure of lockdown, there was a reduction in the figure of the vehicle on way, overall lessening in the industrial unit, etc. [5]. This leads to the drop off in the toxic waste emission from the transport and industrialized sector. This has given a question in everyone’s mind about the effect of confinement on the air quality index by analyzing the various air pollutants that are responsible for the change in the air quality index at a certain location [5, 6].

Study and analysis of various air pollutants namely PM$_{10}$, PM$_{2.5}$, NO$_2$, CO, and O$_3$ were done in different cities and countries around the world [5, 7–38]. The report shows the decreasing trend of PM$_{10}$, PM$_{2.5}$, NO$_2$, and CO but O$_3$ shows enhancement. Above the Indian region, air quality has shown enhancement in the atmosphere class during the time of confinement [7, 18–25]. From the duration of March 3 to the April 14, 2020, Mahato et al. [7] analyzed the CPCB actual time atmosphere class data for 34 locations in Delhi and has inferred loss in PM$_{10}$, PM$_{2.5}$, NO$_2$, and CO which has led to improved air quality index by 40–50%. Sharma et al. [20] showed a decrease of 43%, 31%, 10%, and 18% in PM$_{2.5}$, PM$_{10}$, CO, and NO$_2$ correspondingly using the CPCB data for 22 locations in India for the small duration of March 16 to April 14, 2020. Later,
from March 25 to April 6, Jain and Sharma [18] inferred the decrease of PM$_{2.5}$ by 41%, PM$_{10}$ by 52%, NO$_2$ by 51%, and CO by 28%. Sarfaraj et al. [22] inferred using the CPCB and satellite imagery data over Mumbai and Delhi which showed the loss of NO$_2$ by 40–50% during the lockdown. Srivastava et al. [21] also reported the decrease in four pollutants over Lucknow and New Delhi. Kumari and Toshniwal [25] demonstrated that in small cities there is low reduction than in metro cities.

Navinya et al. [23] examined the loss inside atmospheric parameters in PM$_{2.5}$, PM$_{10}$, NO$_2$, and CO for 17 places showing maximum reduction during morning and evening hours. Studies were targeted over the cities or for a short time which was not coinciding with the actual lockdown period. Apart from this fact, the studies considered the data for less than three weeks. Based on the several factors, it is stated that some of the other factors lead to improvement/deterioration of the air quality.

For the present study, we have taken 13 different stations from all over India whose pollutants data has been taken from Central Pollution Control Board (CPCB) Delhi. The present analysis depends upon parameters of air pollutants (PM$_{10}$, PM$_{2.5}$, SO$_2$, NH$_3$, NO, NO$_2$, NO$_x$, and CO) for all the lockdown phases in INDIA and the stage of unlocking 1 in which certain things were released but still, there was confinement phase.

The lockdown phases are as follows: Initial confinement from 03/25/2020 to 04/14/2020, subsequently from 04/15/2020 to 05/03/2020, from 05/04/2020 to 05/17/2020, and lastly the confinement from 05/18/2020 to 05/31/2020. In continuation, the unlock-1 is from June 1 to June 30, 2020. Through this paper, one can study the pre and post-duration effect of lockdown on the various atmospheric parameters over the several stations in INDIA. This work has been arranged systematically with an explanation of the Introduction in Sect. 1, data and methodology in Sect. 2, results and discussion in Sect. 3, and lastly the conclusion in Sect. 4.

2. Data and methodology

For the study of our work based on the effect of pre and post-lockdown in INDIA during the pandemic situation of Covid-19 on the atmospheric parameters, we have the dataset for the eight parameters named PM$_{10}$, PM$_{2.5}$, SO$_2$, NH$_3$, NO, NO$_2$, NO$_x$, and CO from Central Pollution Control Board (CPCB) Delhi (app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqmlanding/caaqm-comparison-data).

Out of the locations under study, those cities and stations were considered whose complete set of data for eight parameters are available. Various stations covered are from the eastern and western parts of the Indian region. Places from other regions are not considered due to the unavailability of sites. For the duration of data, we have taken a daily six months dataset which is from January to June 2020 for the eight parameters mentioned above. It covers the pre and post-lockdown duration. The average period of the data is 24 h for each month.

3. Results and discussion

For the comparative study of various atmospheric parameters, we have taken 13 locations which if being from the same state and city then different stations are taken. The eight parameters taken for the analytical purpose have been divided into two groups. Group 1- contains NH$_3$, NO, NO$_2$, NO$_x$. The NO$_x$ includes NO and NO$_2$ but here at all locations, separate values have been taken for NO$_2$, NO, and NO$_2$ to diagnose their value and effect individually due to the confinement declared in INDIA. The Group 2 pollutants are PM$_{10}$, PM$_{2.5}$, SO$_2$, and CO. The comparative values of the various pollutants at different locations are shown in Table 1. The 13 locations are named as location 1- Greater Noida, U.P.; location 2- Guwahati, Assam; location 3- DTU, Delhi; location 4- Bollaram Industrial Area, Hyderabad; location 5- Sion Mumbai; location 6- Bhindi, Rajasthan; location 7- Bulandshahar, U.P.; location 8- Vadodara, Gujarat; location 9- Alwar, Rajasthan; location 10- Tirupati, Andhra Pradesh.

Relevant to the lockdown case, as per the lockdown stages in India, five lockdown stages are taken and the 5th stage was with minimal opening, so it is also considered under the lockdown stage, i.e., 06/01/2020–06/30/2020. The Air Quality Index (AQI) is shown in Table 2. The breakdown (%) of air pollutants during the 2020 confinement is shown in Table 3. To study the relationship between meteorological parameters and the COVID-19 pandemic, the meteorological parameters like air temperature (AT) in °C, relative humidity (RH) in %, barometric pressure (BP) in mmHg, and wind speed (WS) in m/s have been taken for the location Mundka, Delhi. The variations of the meteorological parameters during the study period from 01/01/2020 to 06/30/2020 are shown in Fig. 1. From Fig. 1, it is observed that air temperature (AT) and wind speed show an increasing behavior from Jan. 2020 to June 2020. In addition to it, the trend has rapidly increased from March to June 2020 with a temperature value from 15 to 38 °C. Similar behavior is shown by wind speed (WS) from March to June 2020 with an increased value from 0.48 to 2.41 m/s. Barometric pressure (BP) shows a slight increasing behavior from 971 to 996 mmHg and the relative humidity show the ascending trend from 32 to 82% overall but from March to May 2020, the relative humidity
has shown some decreasing trend and then it ascends till June 2020. It is known that positive cases were there from March 2020 to June 2020 and the wind speed variation shows that COVID-19 can be floating in the air either in closed or open environment [39–41]. It can be inferred that these meteorological parameters are responsible for the increase in COVID cases. The result is very well agreed with that of other related works [3, 39–41].

To compare the variation of various air pollutants namely PM 10, PM 2.5, SO2, CO, NH3, NO, NO2, and NOx during the lockdown periods in 2020 with that of the previous year of 2019 during the same period we have plotted their variations in Figs. 2 and 3 at DTU, Delhi station. From Figs. 2 and 3, it is observed that for the lockdown period in 2020 most of the pollutants show a declining trend as compared to the values obtained for the same parameters for the previous year 2019. Thus it can be said that during the lockdown when there was no transport, gathering, etc., and everyone was there at their home, the air pollution levels were decreased it was a good measure to control positive COVID-19 cases. It can be seen that for the Delhi station all air pollutants have shown a drastic fall during the lockdown except the ammonia (NH3) which has shown an increase of 77%. The pollutants PM10 showed a fall of 46.85%, PM2.5 showed a decrease of 20.18%, SO2 showed a fall of 30.74%, CO showed a fall of 51.06%, NO falls by 64.87%, NO2 falls by 44.86%, and NOx falls by 52.44%. Similar trends are also followed by other stations taken for the study. Thus it is inferred the lockdown was good control over the transmission of the pandemic COVID-19. Some parameters showed increased activity at a few locations like Delhi has shown for NH3 which may be due to the reason of dust activities, confinement relaxation or due to the liquor ammonia industries, cyclic change to summer, environmental sites, and biomass consumption that has defused the fall of NH3.

It was observed that Delhi and U.P. were remarked in the category of severe/hazardous, while others come in the category of deprived, modest, and acceptable. Location 1 is taken as Greater Noida in U.P. which is at the junction of the western and eastern devoted goods corridor. It is the gateway to the Delhi–Mumbai manufacturing passage (DMIC). It is one of the largest industrial townships in Asia and lies within the NCR of New Delhi. As shown in Fig. 4(a, b), considering the pollutants as PM10, PM2.5, SO2, CO, NH3, NO, NO2, and NOx and comparing the post-lockdown values from the pre-lockdown values, it is
observed that there is a sharp change with a decrease of 38%, 66%, 9%, for PM$_{10}$, PM$_{2.5}$, SO$_2$, increase of 17% for CO, and decrease of 50%, 53%, 57%, and 56% for NH$_3$, NO, NO$_2$, and NO$_x$ the nitrogen-containing compounds, respectively. This change is due to the debarring of transport, industries, and other human involving activities. This is the main factor in India as the lockdown was implemented for the pre-mentioned tenure throughout India.

The second location taken as Guwahati, in Assam is the largest metropolis in the northeast India. It is known as the entrance to North East India. Economic activity includes petroleum, oil refineries, tea manufacturing, and processing. At this place, the PM$_{10}$ and PM$_{2.5}$ show a decrement of 52 and 61%, SO$_2$ shows an increase by 16% and then CO decreases by 54%, and Ammonia (NH$_3$) decreases by 26%. In Guwahati, NO, NO$_2$, and NO$_x$ show the declining value like 78%, 21%, and 85% systematically as shown in Fig. 5(a, b). The third location has been taken as Delhi Technical University (DTU) located in Delhi is ranked 2nd and 36th among the Best Technology Universities in India. Delhi is the second wealthiest city in India after Mumbai. It is the major marketable hub of northern India. The AQI of Delhi is usually moderate (101–200) between January and September which further severely degrades to extremely deprived (301–400), harsh (401–500), or dangerous (500 +), levels between October and December. This may be owing to stable flaming, firecrackers in Deepawali, and the icy climate. At DTU, Delhi, the particulate matter PM$_{10}$, and PM$_{2.5}$ shows a decrement of 36% and 62% in order. SO$_2$ shows a decrement of 32%. Carbon monoxide (CO) shows again the deferment of 67%. NH$_3$, NO, NO$_2$, and NO$_x$ serially show a decrease of 62%, 83%, 62%, and 76% as shown in Fig. 6(a, b).

The Bollaram Industrial area of Telangana is a fraction of the Hyderabad urban province. Many industries in the vein of Rampex labs, Dr. Reddy’s Labs, Khetan, Coca Cola, Sujana, Mylan, Aparna, Aurbindo Pharma, etc., systematically are available here. The particulate matter PM$_{10}$, PM$_{2.5}$, and SO$_2$. CO shows the fall of 26%, 33%, 4%, and 27%. On the other hand, NH$_3$ shows an increase of 120.68%. Besides this, NO, NO$_2$, and NO$_x$ show a decrease of 2.9%, 45.7%, and 38.68% which has been also shown in Fig. 7(a, b). Sion, the neighborhood of Mumbai, is a village formed by the boundary between Mumbai and Salsette Island. Mumbai is the sixth most popular metro-politician area in the world. It is located on the Konkan coast and has a profound regular port. It is the world’s top ten centers of commerce. It is the financial, commercial, and
entertainment capital of India. At this location, the particulate matter shows a decrease of 67.6% and 72.3%, respectively, for PM$_{10}$, and PM$_{2.5}$. SO$_2$, the sulfur dioxide shows an increase of 84%. Besides this, CO, NH$_3$, NO, NO$_2$, and NO$_x$, show the deferment percentage of 99.9%, 42.9%, 74.9%, 73.3%, and 72.06% as shown in Fig. 8(a, b).

Bhiwadi is located in the Alwar region of Rajasthan. It is an industrialized center, containing huge, average, and microscopic level industry similar to steel mills, furnaces.
to automobiles, and electronics built-up. For this location, in serial order for PM$_{10}$, PM$_{2.5}$, SO$_2$, CO, NH$_3$, NO, NO$_2$, and NO$_x$ shows the deferment by 50.8%, 60.9%, 64.6%, 41.5%, 31.6%, 58.3%, 43.1%, and 50.7% as shown in Fig. 9(a, b). Bulandshahar is the urban panel in the Bulandshahar region of Uttar Pradesh. It is a trade center for agricultural products. In order, PM$_{10}$, PM$_{2.5}$, SO$_2$, CO, NH$_3$, NO, NO$_2$, and NO$_x$ showed the percentage difference by 10.4%, 56.9%, 43.5%, 25.7%, 27.7%, 85.2%, 57.7%, and 72.02% as shown in Fig. 10(a, b).

Vatva is located in the Ahmedabad District. It is one of the largest and oldest industrial estates in the state. Its
proud stalwarts are Godrej, Parle, Intas, Torrent, Nirma, etc. It has overall decreasing trends for the air toxic impurities called PM$_{10}$, PM$_{2.5}$, SO$_2$, CO, NH$_3$, NO, NO$_2$, and NO$_x$ shows a decline in values by 36.67%, 53.66%, 5.85%, 41.16%, 92.87%, 82.97%, and 87.85%, respectively, as shown in Fig. 11(a, b).

Alwar located at a distance of 150 km south of Delhi and 150 km north of Jaipur is in the Alwar region of Rajasthan. It is known for farming creation. It has also the business estate likewise Alwar, Bhiwadi, Shahjahanpur, Neemrana, and Behror. Here the sectors like G.S. pharmabutor, Ashok leylean, Pepsi, Parryware, Kajaria, Ceramics, and Honda Motors have industrial units. It
showed all the decreasing trend for the various air pollutants named earlier in order with values shown as 17.55%, 32.89%, 35.26%, 44.36%, 30.2%, 74.74%, 45.45%, and 54.52% for PM$_{10}$, PM$_{2.5}$, SO$_2$, CO, NH$_3$, NO, NO$_2$, and NO$_x$, respectively, as shown in Fig. 12(a, b). Tirupati is the region in the Chitor area of Andhra Pradesh. It has an industrial facility for mobile handsets and electronics. It has the establishment of Celkon, Micromax, Karbonn, and
Lava. Dixon Technologies has an industrial sector that produces smart TVs for Xiaomi. Tirupati has shown CO to be increased by 10.86% and pollutants as PM$_{10}$, PM$_{2.5}$, SO$_2$, NH$_3$, NO, NO$_2$, and NO$_x$ shows declining values as 36.67%, 53.6%, 5.85%, 41.16%, 92.87%, 82.97%, and 87.85%, respectively, as shown in Fig. 13(a, b).

As inferred from the result stated, it is observed that particulate matter PM$_{10}$, PM$_{2.5}$, and NO$_x$ has shown a
decrease in the post-lockdown duration when compared to the pre-lockdown down for all the seven locations taken. This is due to several reasons such as stopping various human and transport activities, manufacturing industries, navigation activities, lessening of fossil fuel consumption, biomass burning, and continuous functioning of power plants. The declining result obtained for all the noted spots and pollutants is in good agreement with the analytical result as discussed by [1, 3, 42] in their respective studies. Sreekanth et al. [43] during their relevant study for the

Fig. 7 Variation of atmospheric impurities during pre- and post-lockdown observed at Bollaram Industrial area in Hyderabad
Bengaluru station found no significant lessening of PM$_{2.5}$ at all within the station. It was observed that the lessening of the particulate matter stayed nearly constant across the duration. Guttikunda et al. [44] during the study at the same location cities various factors such as travel, exhaust, industries, domestic emission, brick kilns same as well are the examples responsible for PM$_{2.5}$ emissions. Naturally,
sea–salt, open fires, etc., are responsible factors from nature.

Depending upon the factual and short-time data PM$_{2.5}$ datasets, Navinya et al. [23, 45] reported the reduction in PM$_{2.5}$ levels during the confinement stage after comparing data with pre-lockdown levels at locations of Ahmedabad, a west Indian city, and Mumbai, a western coastal place in India. Similarly, Mor et al. [46] found a PM$_{2.5}$ level reduction in the north Indian region of Chandigarh. Jain and Sharma [18] reported the same trend in the north

Fig. 9 Variation of atmospheric impurities during pre- and post-lockdown observed at Bhiwadi in Rajasthan
Indian city of India of 38 locations within New Delhi. In the northwestern region, within Rajasthan at different sites, in Ajmer, Udaipur same kind of behavior was obtained [47].

On the other hand, SO$_2$ evolved majorly due to the ignition of sulfur holding fuel, i.e., coal, and diesel which are applicable for heat influence industrial units, for conveyance in India [48–50]. Mallik and Lal [49] stated that it can also be due to volcanic eruptions and wildfires. From the result obtained, it is observed that SO$_2$ shows a declining trend at maximum locations but there is a contradiction. SO$_2$ has shown an increase of 16.37% in Guwahati (Assam), 32.82% in DTU (Delhi), and 84.88% in

Fig. 10 Variation of atmospheric impurities during pre- and post-lockdown observed at Bulandshahr in Uttar Pradesh
Sion Mumbai. It is observed that SO₂ levels dramatically did not show the drops as those witnessed for other locations and pollutants. This may be due to the fact that majorly profound manufacturing units depending on coal, were in use at less level and remains unaffected. Wind disturbances in the Indo-Gangetic plain are also one of the
reasons for the same [51]. In Guwahati, Assam as reported by Guttikunda and Nishadh [51] maximum air pollutant source is due to transport, dust, and rest are in less amount.

Similarly, CO, whose main sources are vehicles, machinery that burns relic fuel. Domestic staff is also the source of CO. In contradiction, to other locations, Greater Noida has shown an increase of 17.5%, and Tirupati has shown an increase of 10.86%. This change can be estimated from the cookery actions and relocation of the low salaried people. Biomass or biofuels for cooking is the

Fig. 12 Variation of atmospheric impurities during pre- and post-lockdown observed at Alwar in Rajasthan
major contribution to CO emissions [51]. In support of this, it may be due to the reason of agricultural waste burning, corrosion of hydrogen-containing carbons, and burning of relic fuel [52]. Other locations have shown decreasing trend because of restrictions on vehicle movement. NH₃ known as ammonia has an agricultural base, counting living being maintained, the use of ammonia-based fertilizers is the largest source. Besides this ammonia includes manufacturing activities, emissions from vehicles, the process of evaporation from the soil, ocean, etc. It is concerning

Fig. 13 Variation of atmospheric impurities during pre- and post-lockdown observed at Tirupati in Andhra Pradesh
because it causes the formation of tiny substances in the air [53]. From the analytical Table 1, the Bollaram Industrial region of Telangana showed an increase of 120.68%. It can be estimated because of places being an industrial area, especially the manufacturers of liquor ammonia are situated here.

NO₂, NO, the nitrogen oxides occur due to lightning stroke that produces atmospheric oxygen, nitrogen from nitric oxide which further reacts with O₂ to form nitrogen dioxide. Major sources of NO₂ are plants, lightning, and transport section [20, 54]. From human sources, it is due to the burning of coal and oil at the units operated electrically. It is also due to the burning of petrol.

Bera et al. [55] reported that modes of transport through roads, trains, air, and water were stopped leading to the decrease in the concentration of CO and NO₂ in Calcutta (Kolkata). The semi-shutting of industrial and transport sectors causes a reduction of SO₂ but due to coal combustion in various thermal power stations, SO₂ has not been reduced noticeably. Lessening of PM₁₀ and PM₂.₅ has been noticed due to the gradual fall of fossil fuel burning, transport activities, industrial dust, and the banning of construction work.

4. Conclusions

From the present study, it is concluded that:

(i) The air pollutants PM₁₀, PM₂.₅, SO₂, CO, NH₃, NO, NO₂, and NOₓ show decreasing behavior when the post-lockdown values are compared with the pre-lockdown values. These air pollutants during the lockdown period in 2020 also show a declining trend compared to the values obtained for the same parameters for the previous year 2019.

(ii) At some locations, air pollutants, SO₂, CO, NH₃, NO, and NO₂ have shown contradiction. Likewise, CO shows an increasing trend in Greater Noida and Tirupati. This dissimilarity can be due to cooking activities, migration of low-income groups, due to agricultural waste burning, corrosion of hydrogen-containing carbons, and burning of relic fuel [36, 51, 52].

(iii) Few locations such as Guwahati, DTU, and Sion showed the rise in the value of SO₂ due to the presence of several industries that depends on coal power plants, coal mining, etc., which were operating at a low level remains unchanged and also due to wind disturbances in the Indo-Gangetic Plain (IGP) transport [36, 51].

(iv) On the other hand NH₃, NO, NO₂ as the report obtained, increase due to the presence of manufacturing companies of liquor ammonia, the seasonal transition to summer, geographical locations, and biomass burning have neutralized the decrease of NH₃, NO, NO₂ [36, 42].

(v) This concludes that the atmospheric features, while the confinement was there with COVID-19 as a reason was improved because the pollutants responsible for the AQI change over various locations in India have shown the fall with few contradictions. Factors responsible for the reduction in the concentrations of air pollutants are mostly, motor vehicles, and emissions from industries. NO, NO₂, NOₓ was reduced due to the lower emissions from transport and particulate matter. CO reduced due to reduction in the industrial section.

(vi) Confinement was implemented in the spring and dry period, but what about AQI during the cold season as it is generally observed that the temperature dips down, the pollution level increases. Along with this study, the government will think over the idea that how to minimize the use of transport, reduce the industrial sector work, biomass burning, etc., like factors to reduce AQI of INDIA throughout the year. The reduction in AQI can help to reduce the spreading of the corona pandemic over the Indian region.

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Availability of data and materials All the data used in the present study are obtained from the Centre Pollution Control Board (CPCB): https://app.cpcbccr.com/cctr/#/caaqm-dashboard-all/caaqm-landing/data. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare that they have no competing interests.

References

[1] G Pant et al. Environ. Sci. Pollut. Res. 27 44629 (2020)
[2] Q Bukhari and Y Jameel SSRN. Electron. J. (2020)
[3] S Kumar Sci. Total. Environ. 745 141021 (2020)
[4] D Schoeman and B C Fielding Virol. J. 16 69 (2019)
[5] Y Wang, Y Yuan, Q Wang, C G Liu, Q Zhi and J Cao Sci. Total. Environ. 731 139135 (2020)
