Brick Sector and Air Quality: An Integrated Assessment towards 2020 Challenge of Environment Development

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ABSTRACT

Brick sector is a mainstay of the urban economy of Punjab. The traditional technology of brick making emits a lot of toxic gases and smoke particulates into air. Hence, the Government of the Punjab, Pakistan announced a ban on low technology brick kiln operations during winter season by the end of December 2020. Initially, the existing set up of brick kilns and air pollution levels were evaluated before and during lockdown period using spatial application. Further, environmental parameters such as aerosols, carbon monoxide, ozone, sulfur dioxide and carbon dioxide were determined to analyze the air quality, including metrological factors. Results of the study exhibited that the upper and central regions of Punjab are the major hubs of brick kilns. So, the level of air quality was inconsistent in the study period due to the existence of large mushrooms of brick kilns. Further, despite lockdown the highest concentration of carbon monoxide was recorded in the eastern side of the province, such as Kasur, Lahore, and Sheikhupura. The level of aerosols also fluctuated and shifted its trends in the central and southern part of the province. While SO_2 and CO_2 level declined and revealed a satisfactory level of air quality during shutdown. On the other hand, no significant relation to metrological factors, such as rain, is involved in the pollution reduction. Conclusively, the findings of the present study encourage the government agencies to realign the stringent control measures to improve the quality of air in the winter months using the experience of quarantine in 2020.

1. INTRODUCTION

Brick making (Hossain et al., 2019) is an ancient industry of the world (Maithel and Uma, 2000) and its evolution is recorded around 6,000-7,000 BC (Momčilović-Petronijević et al., 2018). Although brick furnaces are established all over the world (Bandyopadhyay et al., 2006), the highest production (90%) is associated with South Asia (Weyant et al., 2014; Tusher et al., 2018). Among South Asian countries, Pakistan ranked 3rd (Figure 1) in brick manufacturing (Naveen, 2016; Khan et al., 2019) and contributes 3.50% share from 18,000 kilns. In addition, 1.5% is the prime input of this sector (Kataria et al., 2018) in the country's Gross Domestic Product (GDP).

Despite its contribution to the country's GDP and social well-being, the brick industry has remained an unregulated and undocumented sector (Iqbal, 2006) which fulfills the rural-urban bricks demand. However, the operational brick kilns in the country are working on classical low-cost Bull's Trench Kilns (BTK) technology and considered one of the major causes of smog formation. The old kilns technology has adverse impacts on the environment (Bhanarkar et al., 2002), biodiversity (Gupta and Narayan, 2010), and air (Wahid et al., 2014). In addition, brick kilns are the emission discharging workplaces causing gastrointestinal, respiratory, skin, reproductive, and psychosocial diseases (Figà-Talamanca, 2006; Shaikh et al., 2012). Further, Coronavirus have been reported

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to have a positive correlation with air pollutants and the virus can transmit through atmospheric aerosols (Comunian et al., 2020).

Before the pandemic, the Government of Punjab banned the operation of old technology brick kilns to control smog and issued the notification for the conversion of old kilns into new technology. But due to COVID-19 lockdown, all economic and social activities were suspended and conversion process from traditional kilns to Zig-Zag system got paralyzed and fractured the socio-economic level of the province. Therefore, considering the above situation, the objectives of the present study were (i) To provide a comprehensive spatial overview of the brick kilns located in Punjab, Pakistan; (ii) To highlight the air pollutants concentration with special focus on all districts of the Punjab; and (iii) To compare the air pollutants level of February 2020 with the lockdown period (April 2020).

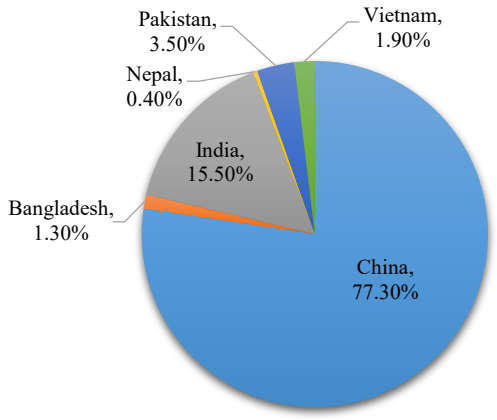

Figure 1. Brick manufacturing in South Asian Countries (Rupan, 2017)

2. METHODOLOGY

2.1 Site description

In Pakistan, 10,347 brick kilns out of 18,000 kilns are established in Punjab (PBC, 2016) and approximately 3.1 million workers are associated with brick manufacturing units in the province. The study site (Javid et al., 2020) presented in Figure 2 comprises of thirty-six districts of Punjab where clusters of estimated brick kilns are contributing to the country's GDP. In Punjab, 38% of bricks supply is produced from the upper and central parts of the districts such as Lahore, Gujranwala, Sheikhupura, Gujrat, Sialkot, Sargodha, Jhelum, and Rawalpindi. While the rest of the districts are contributing 29% share to the country's economy.

In Punjab, brick making is characterized by old modes of brick production which is seasonal and mainly starts in winter season (Khaliquzzaman et al., 2020) (October-November) and lasts until rainy season. The brick manufacturers utilize coal, manure and firewood as fuel which emits hazardous air pollutants which has detrimental impact on environment and human health (Das and Gangopadhyay, 2011).

In Punjab, prior to COVID-19, the province was facing the worst episode of smog (Pervaiz et al, 2020a) when the first coronavirus case was reported on 26th February, 2020 (Badshah et al., 2020) and the percentage of confirmed cases increased rapidly. As the COVID situation got critical, the Government of Punjab Pakistan took control measures against COVID-19 to curb the virus and suspended all economic and social activities. The suspension of human activities not only provided the opportunity to lower the level of air pollution globally (Ramasamy, 2020) but also improved the quality of air in Punjab (Pervaiz et al., 2020a) and smog prone city 'Lahore' (Pervaiz et al., 2020b). On the other hand, the COVID-19 lockdown shut down the brick kilns and affected the socio-economic level (Unni, 2020) badly. Due to this lockdown phase, the forced measures are thought provoking for the government to balance the brick sector and air quality simultaneously to achieve the sustainable development goals.

2.2 Brick kilns classification in Punjab

Brick manufacturing units are like baking ovens (Schmidt, 2013) which are designed to harden the brick material such as clay, soil, and mud. In Punjab, the following intermittent and continuous kilns (Rajarathnam et al., 2014) are operating:

- Hoffman Kiln
- Fixed Chimney Bull's Trench Kilns
- Vertical Shaft Brick Kiln (VSBK)
- Zig-Zag Kiln

2.3 Air quality assessment of Punjab

In order to evaluate the air quality, The modern-era retrospective analysis for research and applications, version 2 (MERRA-2) images were used to analyze aerosol, carbon monoxide, ozone, sulfur dioxide and carbon dioxide concentration in the atmosphere of the two months, February and April 2020. In addition, all data were procured from the world view National Aeronautics and Space

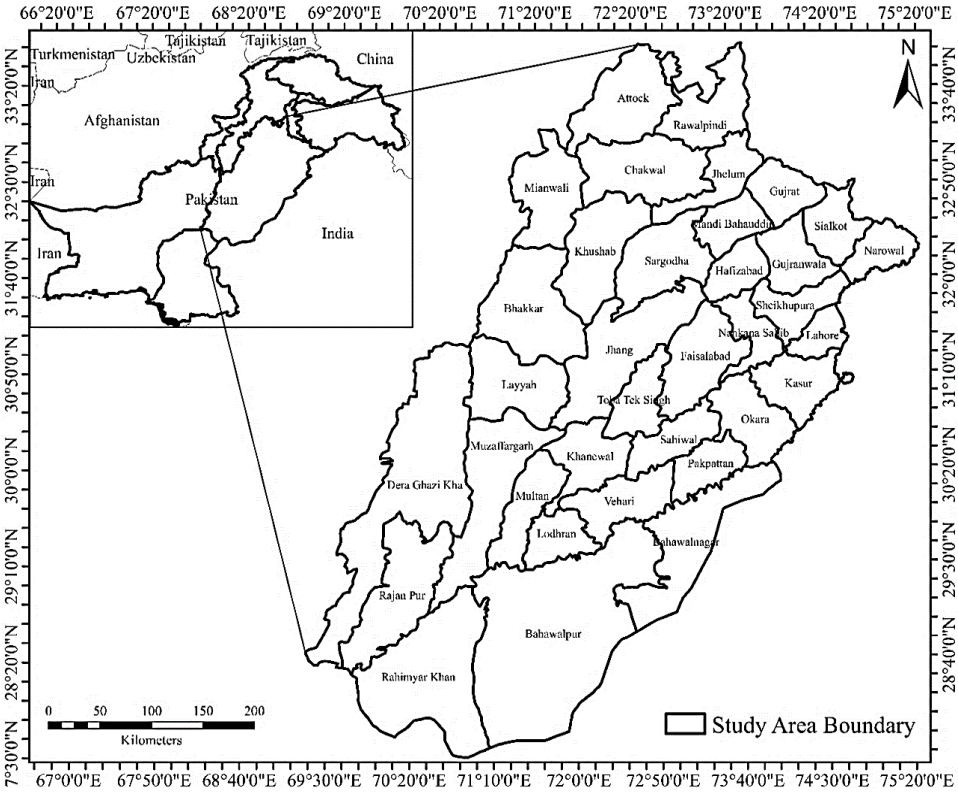

Figure 2. Map of the study site

Administration (NASA) site and processed in ArcGis 10.5 to interpret results. However, the description of spatial data is aggregated in Table 1. In addition metrological factors data of February and April, 2020 was taken from Pakistan Metrological Department (PMD).

Table 1. Description of spatial data

Data set name	Resolution (km)	Month
Total column ozone dobsons (TO_3)	0.5 × 0.625	February and April 2020
Co emission (kg/m^2/s)	0.5 × 0.625	February and April 2020
Aerosol optical depth Analysis (AOD)	0.5 × 0.625	February and April 2020
So_2 surface mass concentration (kg/m^3)	0.5 × 0.625	February and April 2020
Net ecosystem CO_2 exchange (NEE)	9 × 9	February and April 2020

3. RESULTS AND DISCUSSION

3.1 Brick kiln scenario in Punjab

Brick kilns (Kamal et al., 2014; Sikder et al., 2020) of Punjab support the country socio-economically. The brick industry flourished in the province due to the availability of abundant raw material, coal (Shahzad and Ali, 2018). Figure 3 represents the distribution of brick furnaces in the province, Punjab. The data reveals that Faisalabad is dominant in all districts by having maximum number of brick kilns as shown in Figure 3.

In addition, 10 out of 36 districts of the Punjab have big clusters of brick kilns such as Faisalabad, Kasur, Multan, Vehari, Bahawalpur, Gujranwala, Gujrat, Rahim Yar Khan, Sargodha, and Sialkot (Figure 3). Among all districts, Faisalabad (Mehmood et al., 2018) and Kasur are the main hubs of brick kilns (Kataria et al., 2018). Based upon the recent results, it can be clearly perceived that the smallest brick markets are situated in Chiniot and Attock, having less than 100 kilns. Furthermore, Figure 3 shows the recent estimate of kilns' population has exceeded 200 units in 18 districts of Punjab. Furthermore, the existing old brick kiln technology consumes 160 kg of coal for firing 1,000 bricks on average (Raza et al., 2014) and emits various pollutants. So, disaggregating results further, it is revealed that fairly large set up of brick sector in the province is one of the main causes of

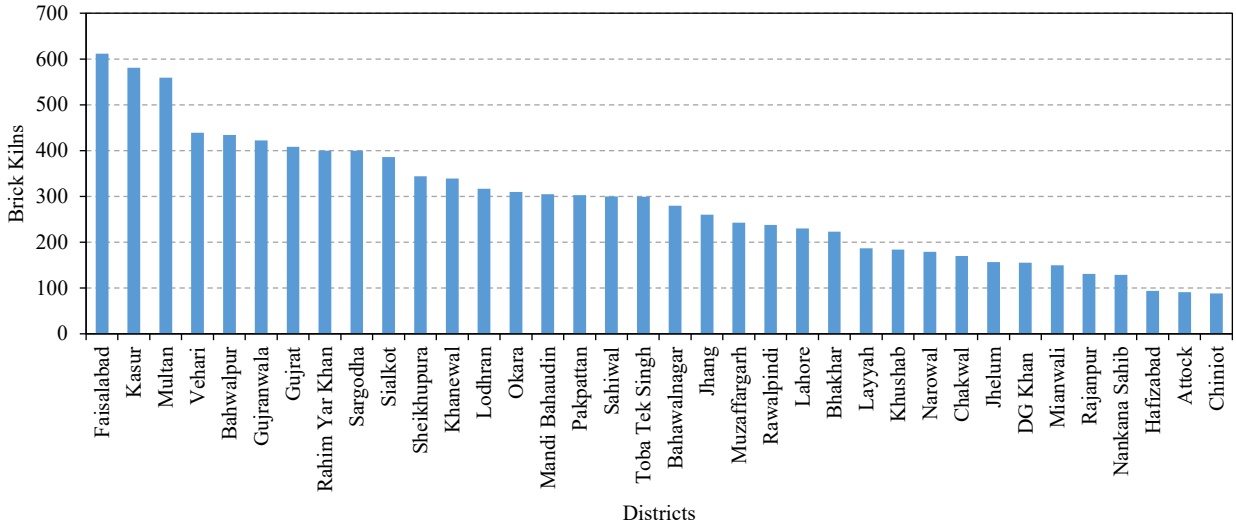

Figure 3. Brick kilns in Punjab (PBC, 2016)

stagnant air. Thus, functioning of old technology kilns in future by delaying in setting up new Zig-Zag system will accumulate emission and increase the proportion of pollutants in the air. Considering further results, it is observed that the brick factories are established in all districts of the province to meet the demand of building material.

3.2 Brick kilns in Punjab

In Punjab, bricks manufacturers are still using old technology for brick manufacturing (Nazir et al., 2011) which is the stationary source (Haque et al., 2018) of air emission (Ismail et al., 2012; Achakzai et al., 2017). As the data of Figure 4 represents the high intensity of old technology kilns are operating in the province which is the largest contributor of air pollutants. The air pollutants level regarding old technology brick kilns are associated with the use of different types of fuel (Sanjel et al., 2016), such as coal (Kumar et al., 2016), old tyres (Gomes and Hossain, 2003; Joshi and Dudani, 2008), agricultural residues (Hameed et al., 2018), bagasse (Kazmi et al., 2016), wood (Tahir and Rafique, 2009; Skinder et al., 2014), industrial waste (Peter et al., 2018), biomass (Zhong et al., 2019), and manure (Blackman, 2000).

So, the fuel consumed in old technology brick kilns pumps out the harmful noxious gases such as sulfur dioxide (SO_2), carbon dioxide (CO_2) (Nepal et al., 2019), carbon monoxide (CO) (Guttikunda et al., 2013), particulate matters (PM) (Aslam et al., 1994; Suresh et al., 2016), volatile organic compounds (VOCs) (Salve et al., 2007), oxides of nitrogen (NOx) (Khan and Vyas, 2008), sulfur (SOx), carbon (COx) (Sanjel et al., 2016), polycyclic aromatic hydrocarbons (PAHs) (Saikia et al., 2016), dioxin (Khan et al., 2015), and furans (Hilten et al., 2008). In addition, stack and fugitive emissions (Rajarathnam et al., 2014; Chen et al., 2017) are discharged from old technology brick kilns during the different process (Darain et al., 2016) such as firing (Sanjel et al., 2017), loading and unloading bricks (Khan et al., 2018), coal crushing (Kumbhar et al., 2014; Pokhrel and Lee, 2014), and cleaning ash of trench (Mondal et al., 2017).

In addition, lack of basic information and technical knowledge of kiln owners, and using substandard kiln technology and cheap fuel to obtain high profit margin are the dominant factors to pollute air. Further, from the perspective of above results it is revealed that in winter the smog is highly dependent on the old technology brick kilns which show their existence in largest number in Punjab.

Whereas, Figure 5 shows that the most of the kilns are closed/abandoned in Attock, Mandi Bahauddin, Sheikhupura, Bhakkar and Muzafargarh. While a very small number of kilns are closed in Rajanpur, Layyah, Vehari, Pakpatan, Bahawalpur, Narowal, and Gujranwala. Das (2015) study has highlighted the reasons to run the brick furnaces on rented land, such as being cost-effective for brick makers. The reasons behind closed and abandoned brick units in Punjab are expired leased contracts and degradation of land (Zhang and Fang, 2007).

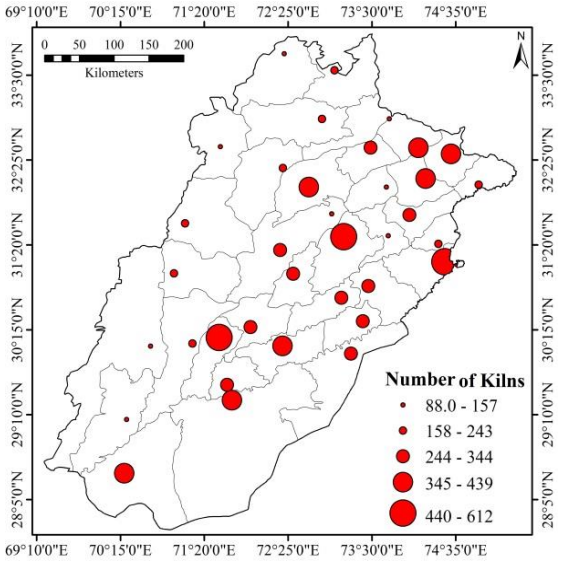

Figure 4. Bick kilns in Punjab

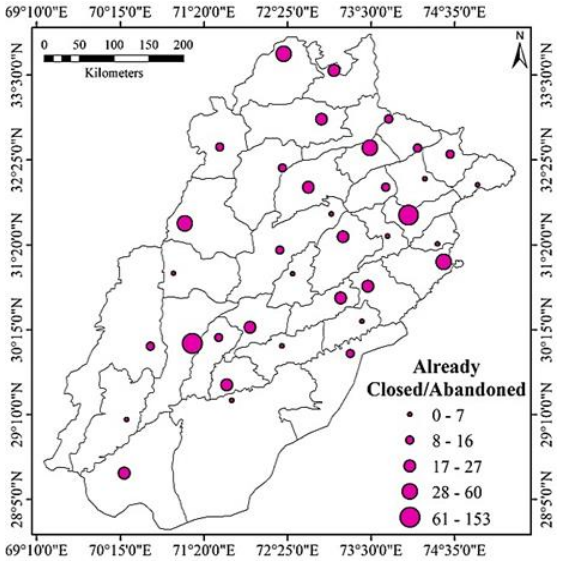

Figure 5. Closed/abandoned kilns in Punjab

3.3 Leased and operational kilns by owners in Punjab

From the granular understanding of Figure 6, it can be clearly seen that the gargantuan size of brick units are operating on lease such as in Gujranwala, Mandi Bahauddin, Okara, Multan, Khanewal, Layyah, and Rahim Yar Khan. In fact, leased land is profitable for manufacturers to run bricks business using local resources (Das, 2015).

Nevertheless, results of Figure 6 indicated that common old technology brick kilns preferred by brick manufacturers because of low investment with high profit (Luby et al., 2015). To date, the unorganized conventional brick kilns are in practice due to financial constraints, erratic power supply and un-trained technicians. Moreover, COVID-19 has been one of the main hurdles (Khan et al., 2020) to switch to resource-efficient Zig-Zag technology, although brick producers are well aware that they are one of the biggest emitters of air pollutants (Khan and Vyas, 2008) and high environmental cost is being paid by the government on the production of construction material resulting in crude emissions which ultimately lead to loss of valuable top fertile soil, biodiversity etc.

Figure 7 results show that least brick units run by the land owners are in Lahore, Narowal, Attock, Rawalpindi, Rahimyar Khan, Bhakar, and Dera Ghazi Khan. Das (2015) study has highlighted one of the major reasons to run the brick furnaces on rented land are economic aspect.

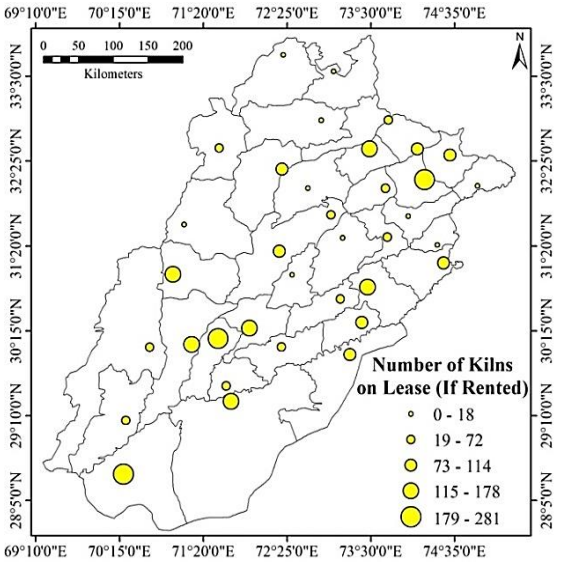

Figure 6. Brick kilns on lease in Punjab

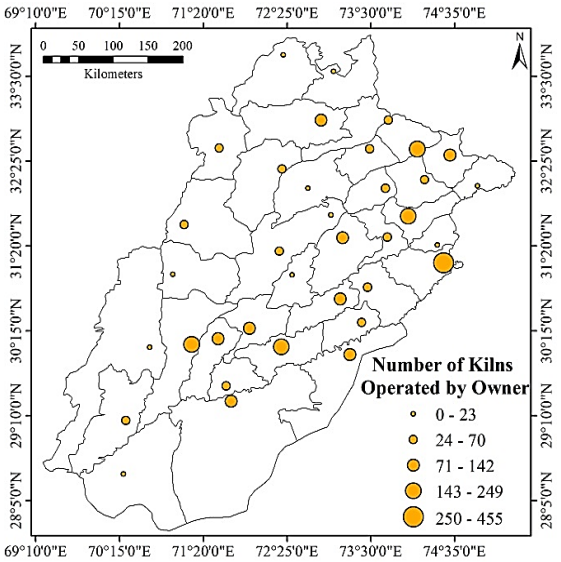

Figure 7. Brick Kilns operated by owner in Punjab

3.4 Aerosol optical depth (AOD) assessment in February and April 2020

Aerosol optical depth (Pathak et al., 2016; Misra et al., 2019) presence in the atmosphere represents the situation of air quality. A low value in terms of palest yellow exhibits a clear sky with high visibility while a reddish colour shows the hazy condition. AOD data highlighted that the particulate matter in Punjab's air is shifting its trends with the passage of time. In the current scenario, in comparison of the results with metrological factor, it is recorded that there is no contribution of rainfall in the AOD level reduction. But the decrease in AOD level is because of COVID-19 lockdown (Kumar et al., 2020). Figure 8 illustrates the highest level of AOD in the northern part of Punjab and lowest level in the southern region of the province. Analyzing the results, it also recorded that the maximum part of the Punjab has the highest level of AOD which is a negative sign for the existing environment. Comparing results of April with February 2020 it is noted that AOD level were reduced during lockdown in the most polluted city of Punjab, i.e., 'Lahore' and supports the findings of the study conducted in Spain (Baldasano, 2020). Kasur which has the highest number of kilns in the province also recorded noticeable results of low AOD. Analyzing Figures 8 and 9, the low concentration is visualized in the northern part and highest level of aerosol is visible in the southern part of Punjab. But overall results of lockdown represent the improved quality of air in April and similar findings have been reported in the study by Gupta et al. (2020).

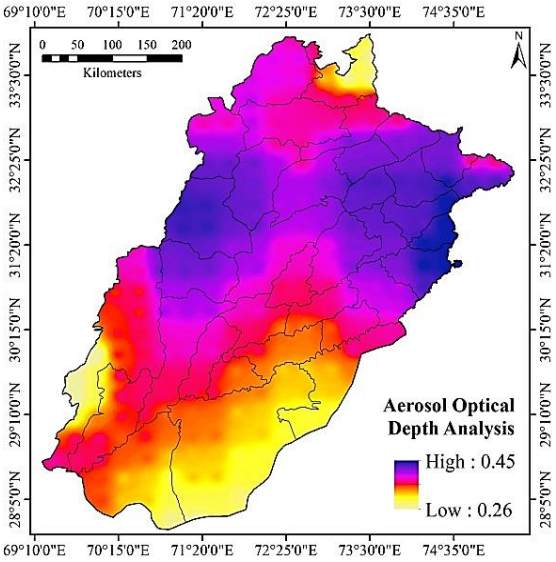

Figure 8. AOD level in February 2020

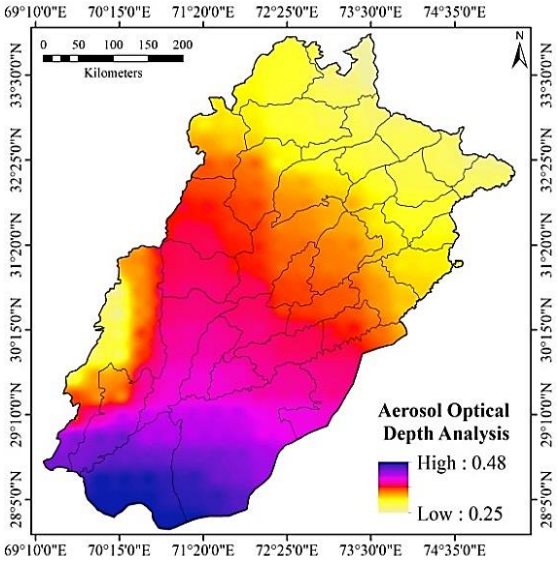

Figure 9. AOD level in April 2020

3.5 Carbon monoxide (CO) assessment in February and April 2020

Carbon monoxide (Guttikunda et al., 2013) is one of the emissions produced by the brick kiln sector (Sanjel et al., 2016). Results of NASA data show the distribution level of CO in the Punjab Province. The satellite-based observations in Punjab exhibit the CO variation before COVID and during the lockdown periods. Analyzing results of the nationwide lockdown has highlighted the prominent reduction in CO level at the study site, similar to results reported in a study conducted by Huang et al. (2020) in China. In addition, Figures 10 and 11 exhibit the CO trend towards the north-eastern zone of Punjab which is the most affected areas of the province in terms of CO emissions, while the south-western region of Punjab is noted with a low level of carbon monoxide during COVID-19 lockdown.

In addition, comparing district wise results, the districts affected by CO are Lahore, Nankana Sahib, Rawalpindi, Sheikhupura, Gujranwala, Sialkot, Narowal, Faisalabad, Kasur, Muzafargarh, and Multan. The prime contributors of carbon monoxide emissions into the atmosphere are thermal power stations and brick industry (Arif et al.,2018) and both of these industries are operating in the highest smog prone districts of Punjab. Further, comparing results with February, it is revealed that intensity of CO is not much reduced in lockdown when all economic and social activities were banned throughout the province.

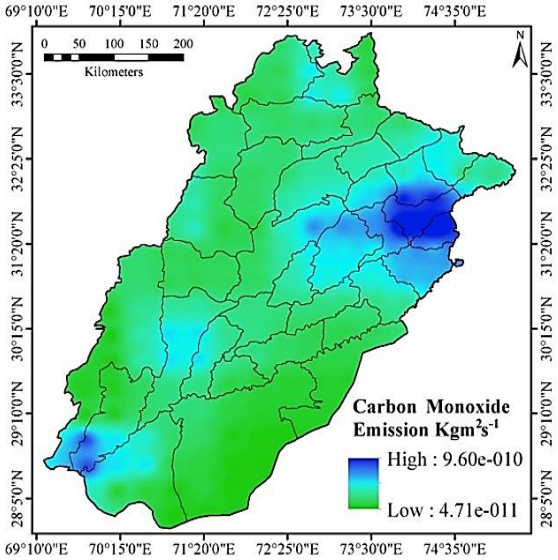

Figure 10. CO level in February 2020

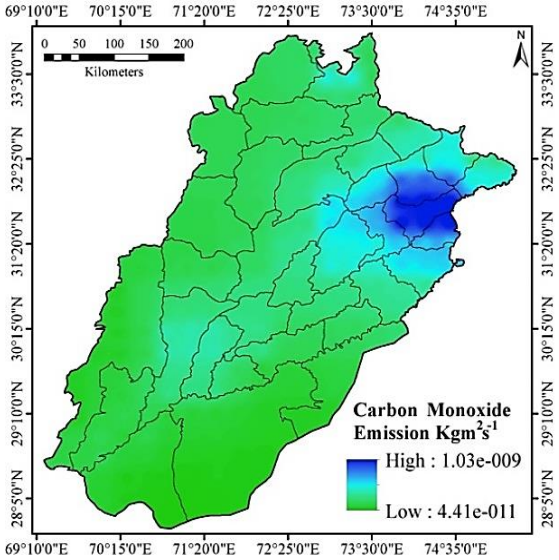

Figure 11. CO level in April 2020

3.6 Ozone assessment in February and April 2020

Spatial trend of ozone in Figures 12 and 13 illustrated that a high proportion of ozone level has been detected in the northern regions of Punjab, similar to results observed in the research conducted in China (Shi and Brasseur, 2020). Analyzing results of the Punjab, it is noted that the intensity of ozone is elevated during lockdown in the central part of the study site. Basic reason for the increase in the level of ozone in Punjab is the reduction of NO level (Quan et al., 2014) during lockdown. Therefore, in lockdown period i.e., April 2020, the ozone level increased when compared to February 2020, which is also supported by the results of recent research conducted by Dantas et al. (2020) and (Collivignarelli et al., 2020).

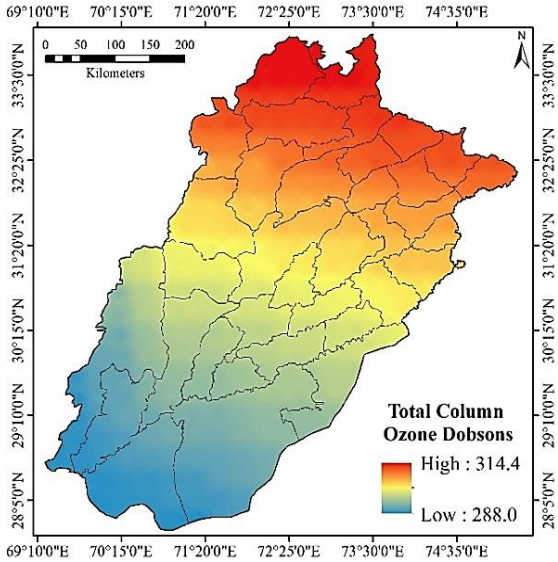

Figure 12. TCO level in February 2020

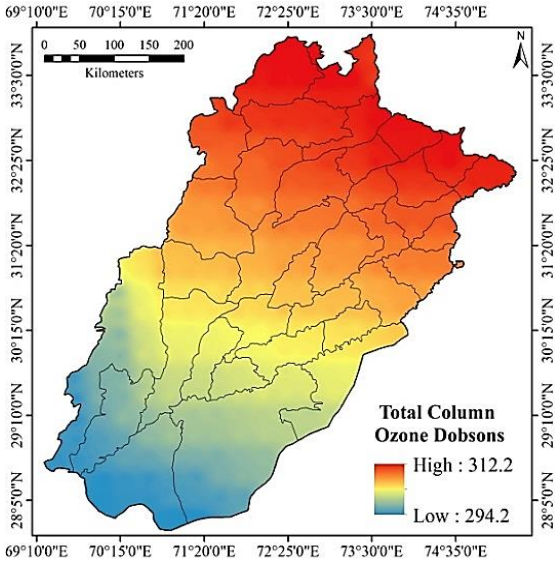

Figure 13. TCO level in April 2020

3.7 Sulfur dioxide assessment in February and April 2020

Brick makers use coal as a primary fuel and significantly rely on it (Alam et al., 2014). Besides coal, the other sources such as old tyres, firewood and waste leather material are also used in kilns as fuel (Sanjel et al., 2016) resulting in sulfur emissions. Considering the spatial pattern of below Figures 14 and 15, a sharp decline is witnessed in sulfur dioxide (SO_2) level all over the Punjab. Although SO_2 (the leading pollutant) associated with brick sector is remarkably decreased, this reduction is not surprising

as it is the outcome of policy measures which were taken to control the deadly virus in the wake of the COVID-19 event. Whereas, during the pandemic, the highest influence of sulfur dioxide is visible in Khanewal, Multan, and Muzafargarh by having large brick sector. Further, it is pertinent to mention here, the distribution level of SO_2 shows that the economic activities were in practice during lockdown in both cities. So, comparing results with Figures 14 and 15 of carbon monoxide also show and support the high concentration of SO_2 level in the similar parts of Punjab. While a medium level of sulfur emissions is seen in the Kasur, Lahore, Nankana Sahib, and Faisalabad which are the known districts of brick kilns. Overall, the minimum level of SO_2 is observed in the maximum parts of the Punjab, which was also witnessed in Morocco (Otmani et al., 2020) during lockdown.

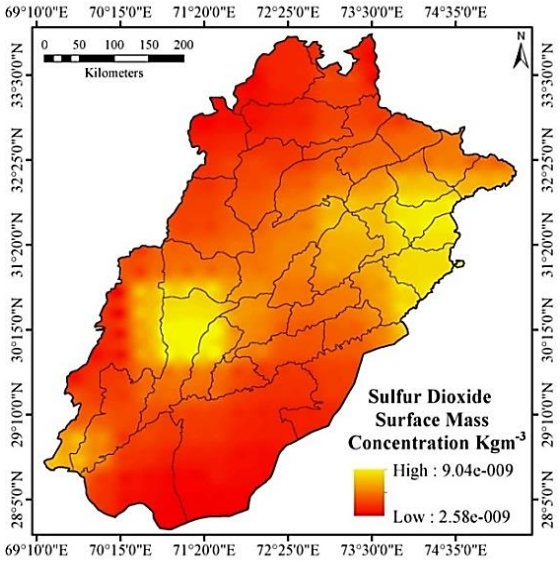

Figure 14. SO_2 level in February 2020

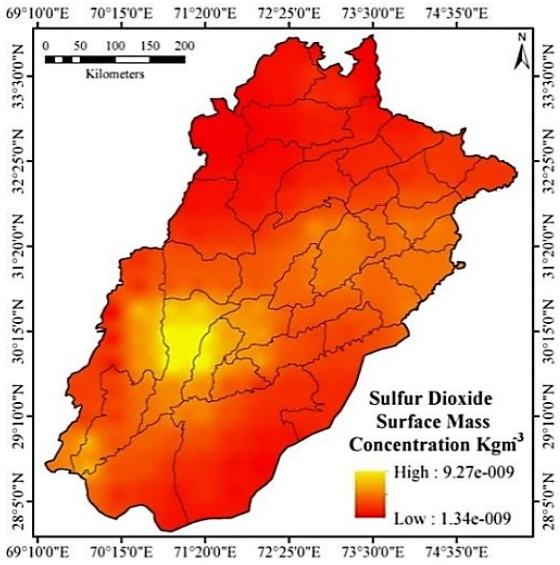

Figure 15. SO_2 level in April 2020

3.8 Carbon dioxide (CO_2) assessment in February and April 2020

The fuel consumed in brick kilns pumps out the harmful noxious gas (carbon dioxide-CO_2) (Alam et al., 2018; Nepal et al., 2019). Figures 16 and 17 have presented the concentration level of CO_2 in February 2020 and April 2020, the lockdown period in Punjab. On comparison, it has been observed that there is noticeable reduction in CO_2 after lock down (March 22nd, 2020). Notably, it is also found that Lahore is one of the most polluted cities of Punjab and, in the present case of suspended human activities, the reduction in carbon emission is visualized in the specific district of eastern side including north-western parts, supporting the findings of the study conducted by Gupta et al. (2020). Thus, the sudden decline in atmospheric CO_2 in most of the Punjab is seen due to the shutdown of industrial units, transport networks and all types of businesses. Similarly, the results of above study support findings of the study conducted in Kolkata during lockdown (Mitra et al., 2020). Further, comparing results with other parts, the high emission level of carbon is visible in the upper and central parts of Punjab such as Rawalpinid (north), Khushab (central), Narowal (north-east), Bahawalnagar (south-east), Rahim Yar Khan (south), and Muzafargarh (south-western).

3.9 Metrological factors in February and April 2020

Meteorological factors determine the quality of air (Kayes et al., 2019). Results of Pre-COVID (Figure 18) depict that highest level of rainfall is received in the northern region of Punjab and very low level is recorded in the rest of the province. So, during COVID-19, the provincial meteorological factors have slight impact on the environmental parameters. In the lockdown period, April 2020, the clear sky provided an opportunity to air pollutants to uplift the concentration of ozone in the northern and central part of Punjab (Figures 18 and 19). The raise in ozone level is due to the reduction of nitrogen oxides which is the outcome of suspended human activities and reported in the study conducted by Spinrad (2020).

Therefore, absence of rains during April did not help in lowering the level of air pollutants in the north

and north-eastern part of the Punjab. On comparison of metrological factors in the Figures 18 and 19, the reduction in environmental parameters (carbon monoxide, carbon dioxide, sulfur dioxide, and aerosol optical depth) is visualized in COVID-19 lockdown.

Conclusively, in the present study, the meteorological elements played no significant role in the reduction of toxic air pollutants. Therefore, this credit only goes to stringent control measures which were imposed to tackle COVID-19 pandemic.

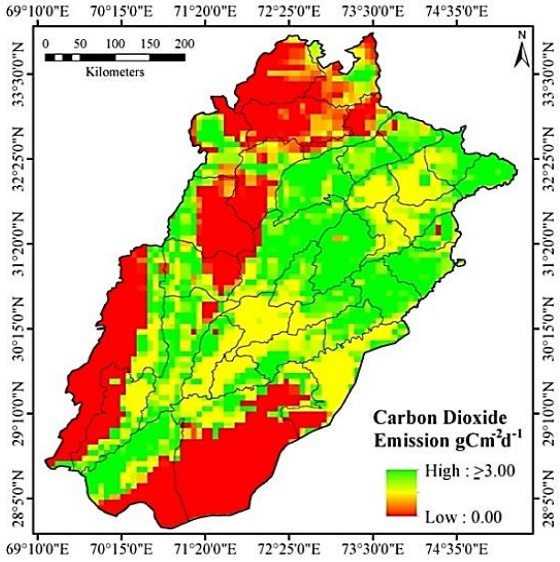

Figure 16. CO_2 level in February 2020

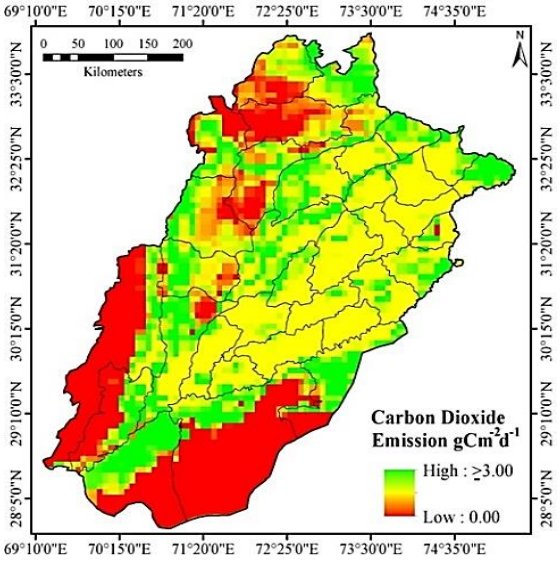

Figure 17. CO_2 level in April 2020

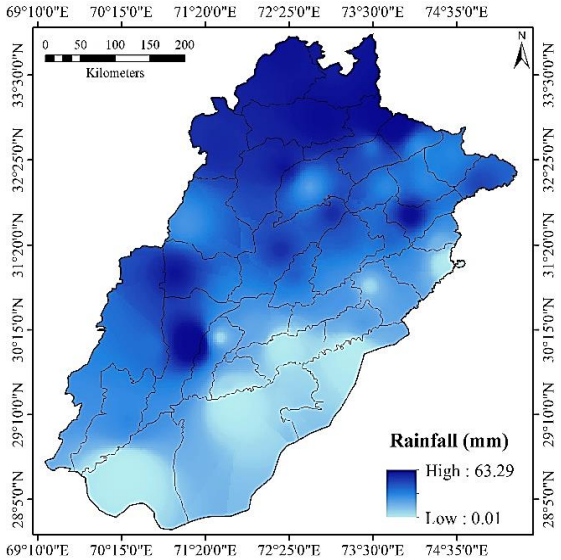

Figure 18. Metrological factors in February 2020

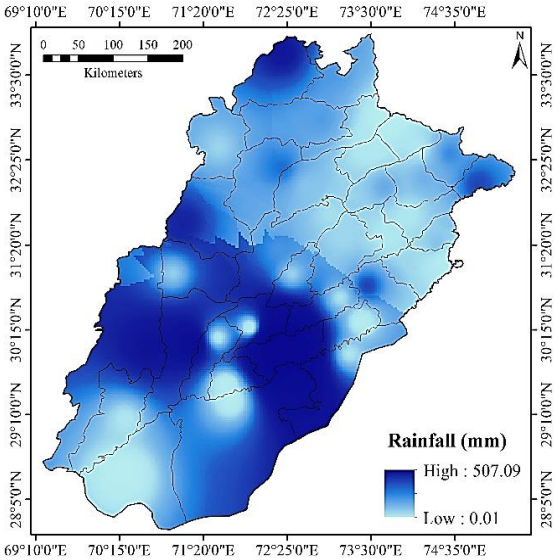

Figure 19. Metrological factors in April 2020

4. CONCLUSION

Results of the present study inferred that Punjab is the hub of brick making units and the fuel used in kilns contributes to degrade the quality of air. Therefore, analysis of spatial results exhibited the fluctuation of aerosol particles and carbon dioxide during COVID-19 lockdown which highlighted the improvement in the air, while the concentration level of CO, SO_2, and TOC depicted the variation throughout the Punjab during the pandemic lockdown. Similarly, like other countries, air pollution is the greatest challenge reported as deadly as Coronavirus. So to overcome air borne sludge and smog menace, the Government of Punjab has banned the operations of old technology brick kilns which are one of the challenges of environmental development in 2020 with Coronavirus. Thus, for the time being the short-term plan can be adopted to hold the level of air

emission by adopting stringent actions using credible monitoring and rigorous enforcement. Using good quality coal, improve feeding and firing practices by retrofitting kilns are another short-term solution to handle the situation. Although, the initiative of Government of the Punjab is commendable to restrain old technology brick kilns emitting hazardous pollutants into air during winter season. In the future, measures like shutting down old brick kilns would be insufficient to control smog like the previous year of 2019. Thus, the way forward for the Government of the Punjab is not only to restrict and stop the old technology brick kilns but at the same time install green belts around the kilns which would be an effective approach to clean foul air. In addition, technical capacity building programs should be initiated to achieve desirable goals by guiding and providing the benefits of clean technology to brick manufacturers.

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