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Comparative Analysis of Air Quality Index in Relation to Crop Residue Burning and Industrial Pollution in Punjab

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ABSTRACT

The stubble burning is considered as the major air pollution contributor during the month of October and November, in Northern parts of India. Due to the fact that it corresponds with the burning seasons, the terrible haze seen over India in the winter has been connected to stubble burning (October-November). The situation is more critical in Punjab as the farmers have adopted extensive Rice-Wheat cropping system which leads to accumulation of stubble at large scale. The major gaseous pollutants generated due to stubble burning and industrial pollution are carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_2), sulfur oxides (SO_2), and methane (CH_4) as well as particulate matters (PM_{10} and $PM_{2.5}$) causing serious issues to human health and the environment. Present study was planned to determine the impact of stubble burning on air quality parameter among industrial, moderately industrial and non-industrial area. It was reported that concentrations of particulate matters $PM_{2.5}$ and PM_{10} in air was increasing with increasing in burning events in all the districts studied. Whereas increasing trend of NH_3 and NO_2 concentration in Ludhiana and NH_3 in Bathinda district may be due the impact of crop residue burning along with industrial pollution. If managed properly, crop stubbles might offer farmers significant economic rewards and safeguard the environment from serious contamination. Present results showed that burning of rice crop residue significantly contributes to air pollution in Punjab.

Keywords Air quality index, Crop residue burning, Industrial pollution.

INTRODUCTION

The daily Air Quality Index depicts the cleanliness and pollution levels of air as well as any potential health risks. The four air pollutants mainly Sulfur Dioxide (SO_2), Oxides of Nitrogen as NO_2, Respirable Suspended Particulate Matter (RSPM / PM_{10}) and Fine Particulate Matter ($PM_{2.5}$) have been considered to check the quality of air. The low AQI (0-50) depicts the good quality, AQI (51-100) satisfactory, AQI (100-200) Moderate and above 200 is hazardous. Earlier vehicles and industry considered as a major air pollution contributor but now crop residue burning (CRB) is new addition. CRB or stubble burning reduces agricultural output, poses a severe danger to the environment, soil fertility, human health and air quality. Stubble burning is the deliberate combus-

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tion of agricultural residue by farmers after harvest. Stubbles are the chopped stalks that are left on the field after the sugarcane or cereal plant stems have been picked for their grains. Including forest fires, burning of stubble accounts for around one-fourth of all biomass burning worldwide (Yadav and Devi 2019, Zhang *et al.* 2016). According to the Food and Agriculture Organization of the United Nations, India is the second-largest crop producer in the world. Each year, India produces over 500 million metric tonnes (MT) of agricultural waste, of which 100 MT is burned. Residue burning is a common practise that follows the harvests of rice in October-November, predominantly in Northwest India (Punjab, Haryana, Uttar Pradesh) (Bikkina *et al.* 2019, Gustafsson *et al.* 2009). Burning residue considerably increases the quantity of particulate matter, such as $PM_{2.5}$ and PM_{10} (Bikkina *et al.* 2019). Sulfur dioxide (SO_2), volatile organic compounds (VOCs), nitrogen oxides (NOx), carbon monoxide (CO), and particulate matter (PM) are all increased by CRB, which has an impact on ambient air quality (Stegarescu *et al.* 2020, Ravindra *et al.* 2019).

In India, New Delhi and the other NCR (National Capital Region) cities have been dealing with severe smog and haze pollution brought on by a variety of anthropogenic activities, as well as lower wintertime temperatures, particularly from October to December every year. Exposure to ambient $PM_{2.5}$ from burning agricultural residue is particularly linked to a three-fold increased risk of acute respiratory illness among Indian population (Chakrabarti *et al.* 2019). The Indian Government's current laws, which include crop residue management, burning prohibitions and penalties, have had a limited impact in reducing agricultural fires (Bhuvaneshwari *et al.* 2019, Shyamsundar *et al.* 2019). Contrary to other agricultural leftover, rice and wheat residue have limited potential for use in biofuel, animal feed, fertilizer and paper manufacture because to their low protein content (e.g., N, P, K) and poor digestibility (e.g., high silica and ash). The effects of stubble-burning extend beyond soil, air quality and human health. In addition to negatively affecting tourism, agricultural production, farmers' socioeconomic status, and the climate, stubble-burning has a number of other negative repercussions on economic growth (McDuffie *et al.* 2021, Cusworth *et al.* 2018). Including the following topics : (1) the creation and burning of crop stubble, (2) the make up of emissions from crop stubble burning, (3) the transportation and dispersion of these emissions, (4) the effects of crop stubble burning, (5) laws and policies pertaining to crop stubble burning, and (6) alternative methods for managing crop stubbles, this review seeks to provide a thorough analysis of the body of literature on the subject.

MATERIALS AND METHODS

Location

In this study, the ambient air quality index was examined in the Punjab state for pre-burning, burning and post burning periods of *kharif* season i.e. from 15-September-2022 to 15-December-2022. The stratified random sampling technique was used to select the district. The present study was conducted in Punjab state and three districts were selected from three different strata's i.e. industrial district, moderately industrial district and non-industrial district. Ludhiana (Industrial district), Bathinda (Moderately industrial district) and Patiala (Non-industrial district) districts were randomly selected for further study.

Collection of data

The study is primarily based on secondary data for crop residue burning events and Air Quality Index (AQI) parameters, collected from Punjab Remote Sensing Center (PRSC), Ludhiana (https://prsc.gov.in/) and Central Pollution Control Board (https://cpcb.nic.in/), respectively. The dailymean AQI $PM_{2.5,}$ AQI PM_{10}, NO_2, NH_3 and CO was considered as Air Quality Index (AQI) parameters.

Statistical analysis

The data was further subjected to correlation analysis to study the inter relationship between crop residue burning events and air quality parameters. The Karl person correlation coefficients were calculated using the formula of Pearson and Hartley (1954) (Pearson and Hartley 1954).

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

x = Values in the first data set, y = Values in the second data set, n = Total number of values.

RESULTS AND DISCUSSION

Every year, crop residue is burned in India, with rice straw accounting for 40% of the total residue burned. The ambient air quality is greatly impacted by the elevated levels of particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), and nitrogen oxides (NO x) caused by residue burning (Singh *et al.* 2022). According to Sehgal *et al.* (2021), these particulate matter present a greater risk to one's health as well as financial and societal losses.

Effect of crop residue burning on air quality index parameters in Ludhiana district (Industrial district)

The results pertaining to correlation analysis of crop residue burning events and Air Quality Index parameters in the Ludhiana district has been presented in Table 1. It can be seen that correlation coefficient between the crop residue burning events and $PM_{2.5}$ was positive and highly significant (0.514**) which showed that both the variables moved together and were well integrated, implying that concentration of $PM_{2.5}$ increased with the augmentations of crop residue burning events. Furthermore, fire incidence showed positive and statistically significant correlation with PM_{10} (0.474**), NO_2 (0.239*) and NH_3 (0.399**) and non-significant correlation with CO (0.107 NS). Positive contribution of residue burning with all the air quality parameters in Ludhiana district might be attributed to the combination with industrial pollution. Industrial pollution, which includes emissions from factories, and other industrial activities, releases various pollutants into the air, such as particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds. These pollutants can interact with the smoke and emissions from residue burning, leading to a more severe pollution problem.

Bathinda district (Moderately industrial district)

Results present in Table 2 exhibits correlation analysis between crop residue burning events and Air Quality Index components in the Bathinda district. A positive and statistically significant correlation coefficient was

Table 1. Correlation coefficients of crop residue burning events and air quality Index parameters in Ludhiana district of Punjab. *and **indicates level of significance at one per cent and five per cent level, respectively.

Particulars	Burning events	AQI $PM_{2.5}$	AQI PM_{10}	NO_2	NH_3	CO
Burning events	1	0.514**	0.474**	0.239*	0.399**	0.107 ^{NS}
AQI $PM_{2.5}$		1	0.915**	0.592**	0.544**	0.652**
AQI PM_{10}			1	0.432**	0.425**	0.630**
NO_2				1	0.582**	0.533**
NH_3					1	0.214 ^{NS}
CO						1

Table 2. Correlation coefficients of crop residue burning events and air quality index parameters in Bathinda district of Punjab. *and **indicates level of significance at one per cent and five per cent level, respectively.

Particulars	Burning events	AQI $PM_{2.5}$	AQI PM_{10}	NO_2	NH_3	CO
Burning events	1	0.557**	0.351**	-0.109 ^{NS}	0.287*	-0.050 ^{NS}
AQI $PM_{2.5}$		1	0.688**	-0.150 ^{NS}	0.444**	0.068 ^{NS}
AQI PM_{10}			1	-0.192 ^{NS}	0.503**	0.339**
NO_2				1	-0.137 ^{NS}	-0.083 ^{NS}
NH_3					1	0.471**
CO						1

Table 3. Correlation coefficients of crop residue burning events and air quality index parameters in Patiala district of Punjab *and **indicates level of significance at one per cent and five per cent level, respectively.

Particulars	Burning events	AQI $PM_{2.5}$	AQI PM_{10}	NO_2	NH_3	CO
Burning events	1	0.508**	0.484**	-0.150^{NS}	0.180^{NS}	0.549**
AQI $PM_{2.5}$		1	0.960**	0.508**	0.599**	0.623**
AQI PM_{10}			1	0.484**	0.555**	0.574**
NO_2				1	0.744**	0.207^{NS}
NH_3					1	0.435**
CO						1

found between crop residue burning events and PM $_{2.5}$, indicating that the two variables moved together and were well integrated. This finding suggests that the concentration of $PM_{2.5}$ increased with the increases of crop residue burning events. In addition, PM_{10} and NH_3 concentrations were positively and significantly correlated with crop residue burning events. There was an inverse and insignificant relationship of burning incidents with NO_2 and CO might be due to the moderately industrial area.

Patiala (Non-industrial district)

In Patiala district crop residue burning events showed positive and highly significant correlation with CO which indicated that concentration of CO increasing with the augmentations of crop residue burning events. Furthermore, crop residue burning events showed positive and statistically significant correlation with $PM_{2.5}$ and PM_{10}. Whereas, NO_2 and NH_3, showed non-significant correlation coefficient with crop residue burning events which might be due to the non-industrial area (Table 3).

As has been observed in the present study, Torres *et al.* (2019) was also reported the contribution of crop residue burning towards the level of $PM_{2.5}$ concentrations is 15–45 times higher than the WHO safety guidelines in northern India. Effect of crop residue burning on air quality index was also reported by many workers in India as well as other parts of the world especially in South Asia, including Pakistan, Nepal and Bangladesh (Torres *et al.* 2019, Sarkar *et al.* 2018). To mitigate the negative impacts, it is crucial to address both residue burning and industrial pollution. Implementing sustainable agricultural practices that minimize the need for burning, such as mechanized harvesting and adopting alternative uses for crop residues, can help reduce the occurrence of residue burning. Additionally, stringent regulations, emission controls, and the adoption of cleaner technologies in industries can help minimize industrial pollution.

Efforts should also be made to promote awareness among farmers, industries, and the general public about the detrimental effects of these practices on air quality and the importance of adopting more sustainable alternatives. Government intervention, technological advancements, and community participation are key factors in achieving a cleaner and healthier environment.

CONCLUSION

The current study indicates that stubble burning is a major contributor of pollution in northern India from September to December however industrial pollution is also extensively contributing in AQI values of $PM_{2.5}$, PM_{10}, NO_2, NH_3 and CO as a second leading cause of air pollution. An extensive awareness program is required to educate the farmers on the financial and environmental advantages of employing alternative methods for managing crop stubble. Farmers need a straight forward solution, not a sophisticated scientific one.

In order to encourage farmers to adopt residue management techniques that have both sound financial feasibility and economic benefit to them, it is preferable to do so. This will encourage farmers to use crops in a sustainable manner of crop residue management. The industrial pollution also needs to be managed by applying strict laws and advent of latest technology to reduce air pollution.

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