

Original Article

Effect of Stubble Burning on Respiratory Function and Quality of Life in a Rural Community (Punjab, India) – A Prospective Observational Study

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Abstract: Agriculture and agro-based economy are the primary sources of livelihood in India. Agricultural activities not only provides the basic daily needs but also generates crop residues as a by-product, which are typically burned to prepare the fields for the successive crops. Crop residue burning or stubble burning is a simply a practice of intentionally setting fire in the field to get rid of crop residue for planting the next crop, i.e., rice and wheat. The primary aim of the present study is to “assess changes in respiratory function and quality of life of people living in the rural community of Punjab, India and to measure PM_{2.5} level in ambient air” during the study period. Study included “WHO-BREF questionnaire which is a survey of quality of life, monitoring of PM_{2.5} level in ambient air using official data from “Punjab Pollution Control Board, socio-demographic profile of the participants, their Respiratory symptoms if any present was noted.” The mean age among participants was 41.99 ± 11.18. and Male: Female 31.5%:68.5%The mean years of education among participants were 3.52 ± 1.48 and 27 (21.8%) were unemployed as head of the family.13.7% of the participants had a symptom of wheezing: while 86.3% of the participant didn't have it.14.5% of the participants had symptom of Breathlessness/Chest Tightness in the morning, whereas 85.5% had no symptoms. The mean duration of wheezing and tightness of the chest was 2.89+/-3.66. and 1.89+/-2.61, respectively, while the mean duration of shortness breath after exertion was 2.10 ± 2.37. Respectively, 13.7-24.2% of them had several respiratory symptoms mentioned in the result and discussion. On-parametric tests (Friedman test) were used to make a statistical inference as data were not normally distributed, which were statistically significant (p<0.05)3 months each for before, during and after burning respectively have been considered. There was a significant difference between the 3 groups in terms of PM_{2.5} (p <0.05) with the median PM_{2.5} being highest in the period: during burning group.

Keywords: stubble burning, respiratory function, quality of life, rural community

1. INTRODUCTION

Agriculture and agro-based economy are the primary sources of livelihood in India. Agricultural activities not only provide the basic daily needs but also generates crop residues as a by-product, which are typically burned to prepare the fields for the successive crops [1]. Crop residue burning or stubble burning is a simply a practice of intentionally setting fire in the field to get rid of crop residue for planting the next crop, i.e., rice and wheat [2]. RICE (*Oriza sativa*) and Wheat (*Triticum aestivum*) plantation system has a long history in Asia, and this “RWS (Rice-Wheat System)” is one of the major practice systems in India. It covers about 9.5 mha, nearly 90% of the area centered in Indo-Gangetic Plains (IGP)

which spans from the Swat valley in Pakistan through the states of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal in India, and into Nepal and Bangladesh [3]. "Agriculture crop residue burning (ACRB)" is a major source of air pollution in the lower atmosphere. These residues burning typically produces smoke which contains harmful gases, especially greenhouse gases (GHGs) and Particulate matter (PM_{2.5} and PM₁₀) of which 70% of these gaseous are Carbon dioxide (CO₂), 7% Carbon monoxide (CO), 0.66% Methane (CH₄), and 2.09% Nitrogen dioxide (N₂O) [4]. These gaseous and other air pollutants affect the quality of the air, we breathe, leading to the impairment of lung function. When the air pollutant is inhaled in sufficient concentration, it is likely to produce acute neutrophilic airway inflammation associated with symptoms of cough, dyspnea and wheezing [5]. Ambient air pollution has been the subject of growing concern for several decades due to its negative effects on the health as well as on the environment [6]. A number of health problems, starting from disorders in the respiratory and cardiovascular system to mortality, have been associated with air pollution. ". It has been postulated that ultra-fine particles in the air have the ability to penetrate lung walls inducing inflammation in the pulmonary interstitial, which in turn stimulates the production of clotting factors in the blood and intensifies ischemic heart disease [7]. Airborne particles remain suspended in the air for a very long time due to their small size and very lightweight". Therefore, it is important to know particulate matter concentration in the ambient air as it has severe adverse health effects [8]. Rice crop residue burning during mid-October to November is becoming an alarming condition due to the increased burning by farmers in the states of Punjab, Haryana, and western Uttar Pradesh every year. "Crop residue burning started in the late 1980s with the start of mechanized harvesting in Punjab. Farmers found burning to be an economical way of cleaning crop stalk residues that are left over by mechanized harvesters [9]. In the winter season, the severity of this problem increases as dispersion of smoke plumes is slowed down due to the cold temperature" [10]. Among the different diseases "Chronic Obstructive Pulmonary Disease (COPD)" is one of the subjects of interest. It is a disease characterized by a degeneration of lung function over time that is not entirely reversible, and it encompasses both emphysema and chronic bronchitis. Globally, it is considered a significant public health problem, being the second leading cause of mortality. "As of 2016, the Global Burden of Disease (GBD) study estimated that about 3 million people worldwide died of COPD" [11]. Stubble burning is considered the third most cause of air pollution in India after industrial and vehicular emissions. The stubble burning usually occurs during October and November every year after the rice crop is harvested. The residue has to be taken care of for the early preparation of the next crop as this method is cheap and easy for the farmers. However, crop residue burning adversely affects the local and regional air quality, including health effects such as respiratory ailment; resulting in poor the quality of life. Due to a lack of education and training about the proper technique of disposal of crop residue to the farmers and the active participation of government and non-governmental bodies, the practice is prevalent in North-India. Further, few studies focus on the health effects of crop residue burning at a rural location, which is a hot spot of crop residue burning emissions [12]. Hence, the purpose of the present study is to assess changes in respiratory function before and after the burning of stubble and to see the overall impact on Quality of Life (QOL) and simultaneously measure the levels of PM_{2.5} at a rural location, i.e., Khera village, Fategarh Sahib, Punjab. The outcome of the study could help and guide researchers, scientists and policymakers to better understand the associated health effects of crop residue burning, which could provide evidence for formulating pollution control strategies in the future [13]. This study aims to determine the effect of stubble burning on quality of life in a rural community in Khera village, Fategarh Sahib, Punjab, India, to assess the respiratory symptom status during stubble burning using Indian Study on Epidemiology of Asthma, Respiratory Symptoms and Chronic Bronchitis in adults (INSEARCH) questionnaire, to assess the change in the quality of life of people during this period using the WHO BREF scale, to measure PM_{2.5} level in ambient air during the study period and to measure the total number of fire count incidents in the study area during the study period.

2. MATERIALS & METHOD

The study was conducted using an observational study design. The study includes an assessment of respiratory symptoms and quality of life using a standard questionnaire. The study participants from Khera block of District Fategarh Sahib were interviewed using INSEARH and WHO-BREF questionnaire for respiratory assessment and quality of life, respectively. As it was the exploratory study, village was randomly selected near CHC Khera voluntary with the help of MPHW and ASHA worker and all the participant more than 18 and less than 60 were included in the study. The data of $PM_{2.5}$ level was acquired from the neared rural monitoring site situated at RIMT Management College, Mandi, Gobindgarh. The lung function observation of the study participants was planned using spirometry according to standard ATS method but could not perform the measurements due to COVID-19 pandemic and restrictions. Spirometry is a high aerosol-generating procedure with higher chances of transmission of COVID-19. This observational study carried out before, during and after the stubble burning phase. As the study was exploratory in nature, village was randomly selected near CHC (community health center) Khera voluntary with the help of MPHW and ASHA workers. All the individuals enrolled in the study were thoroughly evaluated before the examination for their inclusion in the study. Participants demographic details, along with their respiratory questionnaire and quality of life assessment was undertaken. Study area was Khera block, Fatehgarh Sahib, Punjab, India and the sampling technique used was Routine sampling following CPCB standard methodology for the required sample size, a pilot study on the prevalence of COPD in a rural area of Mysore was considered where the prevalence of the disease was 7.1.

$$N = Z^2_{1-\alpha/2} P(1-P) \div D^2$$

Where N=number of sample size

$Z_{1-\alpha/2}$ = percentage point of the standard normal distribution corresponding to the chosen level of confidence

P =estimated COPD prevalence

d= level of precision, called sampling error

with this formula, sample size (n)

i.e. 98 will be our sample size

Thus, obtained sample size shall be evaluated based on their age, gender, socio-demographic profile. The individuals were asked specific questions to access the respiratory symptom using Indian Study on Epidemiology of Asthma, Respiratory Symptoms and Chronic Bronchitis in adults (INSEARCH) questionnaire during the stubble burning period and WHO Quality of Life (BREF) questionnaire. Data was analyzed “using SPSS version 22.0 and Microsoft Excel 2010”. Matched paired T-test was applied. The normalcy of all-continuous variables like age, SBP, DBP, body mass index (BMI), quality of life score, etc. was checked using the Kolmogorov Smirnov test. Data was expressed as mean $\pm$ standard deviation for normally distributed continuous variables or median (first quartile; third quartile) for non-normally distributed continuous variables.”

3. RESULTS & DISCUSSION

According to previous studies, “one tone stubble burning leads to a loss of 5.5kg nitrogen, 2.3kg phosphorus, 25kg potassium and more than 1kg of sulfur — all soil nutrients, besides organic carbon. Respiratory issues like coughing, wheezing and shortness of breath also prevailed in such areas in the majority of residents. In our study, the demographic details, respiratory effects during burning, quality

of life assessment and comparison of air pollution pre-burning, during burning and after burning have been performed effectively, which is mentioned below.

Table 01: Demographic details of the participants

Socio-Demographic Details	Mean $\pm$ SD Median (IQR) Min-Max Frequency (%)
Age (Years)	41.99 $\pm$ 11.18 42.00 (33.75-51.00) 18.00 - 71.00
Gender	
Male	39 (31.5%)
Female	85 (68.5%)
Years of Education	3.52 $\pm$ 1.48 4.00 (3.00-4.00) 1.00 - 6.00
Occupation of Head of Household	
Worker In a Government or Private Service	43 (34.7%)
Unemployed Or retired	27 (21.8%)
Unskilled Laborer	19 (15.3%)
Business / Self Employed Professional	16 (12.9%)
Housewife	13 (10.5%)
Skilled Laboure	4 (3.2%)
Agriculturist	2 (1.6%)
Supervisor In a Government or Private Service	0 (0.0%)
Officer In a Government or Private Service	0 (0.0%)
Occupation of Respondent	
Unemployed Or retired	13 (10.5%)
Housewife	74 (59.7%)
Worker In a Government or Private Service	24 (19.4%)
Business / Self Employed Professional	5 (4.0%)
Unskilled Laborer	4 (3.2%)
Skilled Laboure	3 (2.4%)
Agriculturist	1 (0.8%)
Supervisor In a Government or Private Service	0 (0.0%)
Officer In a Government or Private Service	0 (0.0%)

Socio-demographic and respiratory questionnaire of the participants, were extracted from “Indian Study on Epidemiology of Asthma, Respiratory Symptoms and Chronic Bronchitis in adults (INSEARCH)” The mean age among participants was 41.99 $\pm$ 11.18. and the Male: Female ratio was 31.5%:68.5%. The mean years of education among participants were 3.52 $\pm$ 1.48. and 27 (21.8%) were un-employed as head of the family.

Table 02: Prevalence of Respiratory symptoms among participants

Symptoms	Yes	No
Shortness of Breath After Exertion	42 (33.9%)	82 (66.1%)
Shortness of Breath on Exposure to Dust/Feathers/Pets	30 (24.2%)	94 (75.8%)
Shortness of Breath Without Exertion	28 (22.6%)	96 (77.4%)
Getting Up at Night Due to Breathlessness	26 (21.0%)	98 (79.0%)

Chest tightness on Exposure to Dust/Feathers/Pets	25 (20.2%)	99 (79.8%)
Cough First Thing in Morning	24 (19.4%)	100 (80.6%)
Expectoration First Thing in Morning	22 (17.7%)	102 (82.3%)
Expectoration Most Morning for 3 Months/Year	21 (16.9%)	103 (83.1%)
Getting Up at Night Due to Cough	18 (14.5%)	106 (85.5%)
Breathlessness/Chest Tightness in Morning	18 (14.5%)	106 (85.5%)
Wheezing	17 (13.7%)	107 (86.3%)

Table 03: Summary of Atopy & Family History

Variables	Frequency (%)
Total no with personal history of on & off Skin Rash	41 (33.1%)
Total no with personal history of Itchiness in Eyes	34 (27.4%)
Total no with personal history of Sneezing/Running Nose	18 (14.5%)
Total no of respondents with Family Members having history of above three symptoms	29 (23.4%)
Other Family Members	20 (68.9%)
Children	4 (13.7%)
Grandparents	3 (10.3%)
Parents	1 (3.4%)
Sister	1 (3.4%)
Total no of respondents with Family Members Suffering from Asthma	14 (11.3%)
Grandparents	5 (35.7%)
Other Family Members	4 (28.6%)
Parents	3 (21.4%)
Brother	1 (7.1%)
Sister	1 (7.1%)

Table 04: Prevalence of smoking

Smoking	Mean $\pm$ SD Median (IQR) Min-Max Frequency (%)
Ever Smoked for ≥ 1 Year (Yes)	3 (2.4%)
Form of Tobacco Smoked	
Bidi	2 (66.7%)
Cigarette	1 (33.3%)
Hookah	0 (0.0%)
Cigar	0 (0.0%)
Pipe	0 (0.0%)
Others	0 (0.0%)
Number of Smokes/Day	4.00 $\pm$ 1.00 4.00 (3.50-4.50) 3.00 - 5.00
Age of Starting Smoking	20.00 $\pm$ 5.00 20.00 (17.50-22.50) 15.00 - 25.00
Smoking Status	
I Still Smoke	2 (66.7%)
I Have Left Smoking for More Than a Year	1 (33.3%)

I Have Left Smoking for Less Than a Year	0 (0.0%)
Age of Quitting Smoking	4.00 ± NA 4.00 (4.00-4.00) 4.00 - 4.00
Tobacco Use Other than Smoking (Yes)	4 (3.2%)
Form of Tobacco Used	
Zarda	3 (75.0%)
Khaini	1 (25.0%)
Pan masala	0 (0.0%)
Gutka	0 (0.0%)
Snuff	0 (0.0%)
Others	0 (0.0%)
Duration of Tobacco Use	12.50 ± 8.66 12.50 (5.00-20.00) 5.00 - 20.00
Number of Chews/Day	3.33 ± 1.53 3.00 (2.50-4.00) 2.00 - 5.00
Family Members Smoke in Your Presence (Yes)	8 (6.5%)

WHO BREF Questionnaire was administrated to the 120 participants out of which 110 were self-administrated and 10 were interviewer assisted. The WHOQOL-BREF is a self-administered questionnaire comprising 26 questions on the individual's perceptions of their health and well-being over the previous two weeks. Responses to questions are on a 1-5 Likert scale where 1 represents "disagree" or "not at all" and 5 represents "completely agree" or "extremely". Domain scores are scaled in a positive direction (i.e. higher scores denote higher quality of life). The mean score of items within each domain is used to calculate the domain score. The WHOQOL-BREF assesses the quality of life (QOL) within the context of an individual's culture, value systems, personal goals, standards and concerns.

Table 05: WHOQOL-BREF domains

Domain	Facets incorporated within domains
1. Physical health	Activities of daily living Dependence on medicinal substances and medical aids energy and fatigue Mobility Pain and discomfort Sleep and rest work capacity
2. Psychological	Bodily image and appearance Negative feelings Positive feelings Self-esteem Spirituality / Religion / Personal beliefs Thinking, learning, memory and concentration
3. Social relationships	Personal relationships social support Sexual activity
4. Environment	Financial resources Freedom, physical safety and security Health and social care: accessibility and quality home environment Opportunities for acquiring new information and skills Participation in and opportunities for recreation / leisure activities Physical environment (pollution / noise / traffic / climate) Transport

Table 06: Gender pattern-wise overall change in BREF questions from 1 to 26 across 3 different time points

	BEFORE BURNING				DURING BURNING				AFTER BURNING			
	Gender		Wilcoxon-Mann-Whitney U Test		Gender		Wilcoxon-Mann-Whitney U Test		Gender		Wilcoxon-Mann-Whitney U Test	
	Male	Female	W	p value	Male	Female	W	p value	Male	Female	W	p value
How would you rate your quality of life?	3.62 (0.59)	3.62 (0.56)	1617.000	0.805	3.32 (0.47)	3.39 (0.49)	1417.000	0.494	2.36 (0.63)	2.39 (0.71)	1584.500	0.663
How satisfied are you with your health?	3.54 (0.76)	3.80 (0.59)	1356.000	0.057	3.43 (0.50)	3.39 (0.49)	1581.000	0.668	2.47 (0.76)	2.11 (0.80)	1935.000	0.023
To what extent do you feel that physical pain prevents you from doing what you need to do?	2.31 (0.47)	2.21 (0.41)	1816.500	0.250	3.11 (0.39)	3.11 (0.39)	1493.500	0.807	3.11 (0.39)	3.11 (0.39)	1493.500	0.807
How much do you need any medical treatment to function in your daily life?	2.21 (1.34)	2.14 (1.28)	1698.000	0.820	1.97 (0.55)	2.01 (0.64)	1481.000	0.809	1.73 (0.65)	1.90 (0.64)	1304.000	0.171
How much do you enjoy life?	4.10 (0.31)	4.12 (0.39)	1628.500	0.802	3.57 (0.60)	3.70 (0.62)	1388.500	0.408	1.51 (0.51)	1.61 (0.52)	1380.000	0.363
To what extent do you feel your life to be meaningful?	3.21 (0.80)	3.11 (0.66)	1734.500	0.616	3.57 (0.65)	3.68 (0.56)	1356.500	0.291	4.36 (0.54)	4.22 (0.52)	1863.500	0.184
How well are you able to concentrate?	4.00 (0.83)	3.80 (0.72)	1920.500	0.124	3.65 (0.63)	3.76 (0.66)	1389.000	0.406	2.92 (0.80)	2.73 (0.75)	1705.000	0.248
How safe do you feel in your daily life?	4.36 (0.81)	4.36 (0.67)	1716.500	0.726	3.41 (0.69)	3.65 (0.71)	1261.000	0.107	3.70 (0.74)	3.94 (0.62)	1271.000	0.108
How healthy is your physical environment?	4.21 (0.66)	4.39 (0.67)	1394.000	0.117	-	-	-	-	3.97 (0.55)	3.88 (0.67)	1643.000	0.414
Do you have enough energy for everyday life?	4.44 (0.72)	4.46 (0.80)	1581.000	0.641	3.53 (0.69)	3.43 (0.74)	1664.000	0.510	4.05 (0.57)	4.13 (0.66)	1398.500	0.434
Are you able to accept your bodily appearance?	2.23 (0.67)	2.26 (0.74)	1668.000	0.952	3.81 (0.66)	3.66 (0.63)	1689.000	0.271	4.41 (0.50)	4.38 (0.51)	1551.000	0.821

Have you enough money to meet your needs?	2.97 (1.16)	2.74 (1.01)	1823.000	0.329	3.78 (0.67)	3.72 (0.67)	1556.500	0.801	4.16 (0.65)	4.24 (0.62)	1419.000	0.528
How available to you is the information that you need in your day-to-day life?	3.79 (1.00)	4.01 (1.02)	1437.000	0.214	3.97 (0.55)	3.72 (0.65)	1848.500	0.032	4.00 (0.53)	3.89 (0.57)	1661.000	0.312
To what extent do you have the opportunity for leisure activities?	3.46 (0.94)	3.76 (0.88)	1365.000	0.078	3.32 (0.75)	3.35 (0.73)	1471.000	0.776	3.35 (0.48)	3.46 (0.53)	1340.500	0.242
How well are you able to get around?	3.00 (0.00)	2.98 (0.73)	119.000	0.954	3.73 (0.80)	3.67 (0.79)	1561.500	0.786	3.57 (0.55)	3.59 (0.50)	1473.000	0.772
How satisfied are you with your sleep?	3.82 (1.14)	3.91 (1.10)	1588.500	0.698	3.73 (0.61)	3.73 (0.72)	1515.000	0.992	3.65 (0.48)	3.59 (0.52)	1601.000	0.571
How satisfied are you with your ability to perform your daily living activities?	3.08 (0.81)	3.21 (0.86)	1484.000	0.307	3.70 (0.66)	3.95 (0.70)	1231.000	0.073	3.51 (0.51)	3.56 (0.50)	1445.000	0.634
How satisfied are you with your capacity for work?	3.79 (0.89)	3.94 (0.88)	1507.500	0.397	3.92 (0.64)	3.82 (0.63)	1641.500	0.420	3.62 (0.49)	3.60 (0.49)	1553.500	0.807
How satisfied are you with yourself?	3.54 (0.68)	3.49 (0.75)	1746.500	0.585	3.73 (0.80)	3.70 (0.68)	1560.500	0.786	3.38 (0.49)	3.56 (0.52)	1251.500	0.080
How satisfied are you with your personal relationships?	4.05 (1.15)	4.21 (0.83)	1611.500	0.792	3.65 (0.59)	3.76 (0.64)	1392.500	0.424	3.65 (0.68)	3.77 (0.59)	1343.000	0.262
How satisfied are you with your sex life?	3.97 (0.90)	4.02 (0.72)	1667.000	0.957	4.03 (0.69)	3.93 (0.64)	1635.000	0.449	4.11 (0.61)	3.94 (0.60)	1727.000	0.159
How satisfied are you with the support you get from your friends?	3.08 (0.70)	3.15 (0.63)	1596.500	0.618	3.35 (0.63)	3.34 (0.65)	1553.000	0.820	2.65 (0.79)	2.62 (0.83)	1543.000	0.874
How satisfied are you with the conditions of your living place?	3.79 (1.15)	3.82 (1.21)	1630.000	0.877	3.46 (0.51)	3.59 (0.52)	1336.000	0.232	2.86 (0.42)	2.87 (0.52)	1525.000	0.955

How satisfied are you with your access to health services?	2.41 (0.72)	2.40 (0.77)	1694.000	0.803	1.81 (0.62)	1.70 (0.60)	1663.500	0.342	2.68 (0.47)	2.71 (0.46)	1469.000	0.732
How satisfied are you with your transport?	2.43 (1.01)	2.40 (0.97)	1535.500	0.914	3.00 (0.91)	2.88 (0.89)	1622.500	0.526	2.22 (0.48)	2.35 (0.76)	1407.000	0.461
How often do you have negative feelings such as blue mood, despair, anxiety, depression?	2.00 (0.47)	1.87 (0.47)	1698.500	0.155	1.76 (0.49)	1.84 (0.60)	1422.500	0.522	1.62 (0.59)	1.83 (0.62)	1258.000	0.093

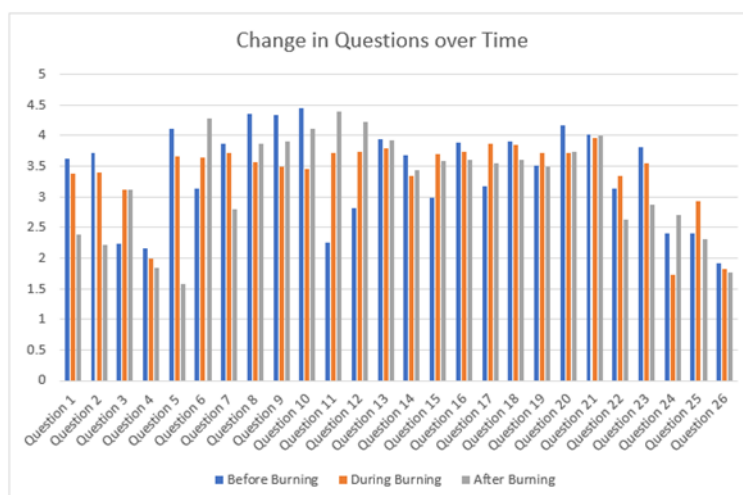


Figure 01: Graphical representation of overall change in questions from 1 to 26 over time in 3 different groups.

Table 07: Change in question no. 8 at 3 different time points

Timepoint	Question 8			Friedman Test	
	Mean (SD)	Median (IQR)	Range	χ^2	P Value
Before Burning	4.36 (0.71)	4.00 (1.00)	2.00 - 5.00	73.0	<0.001
During Burning	3.57 (0.71)	4.00 (1.00)	2.00 - 5.00		
After Burning	3.87 (0.66)	4.00 (1.00)	2.00 - 5.00		

“The mean Question 8 increased from a maximum of 4.36 at the before burning timepoint to a minimum of 3.57 at the during burning timepoint. This change was statistically significant (Friedman Test: $\chi^2 = 73.0$, $p = <0.001$)”. The following is the Box-and-Whisker plot which depicts the distribution of Question 8 diagram depicting the change in over time. The upper and lower bounds of the box represent the 75th and the 25th percentile of the particular question respectively, and the upper and lower extent of the whiskers represent the Tukey limits of the particular question, respectively.

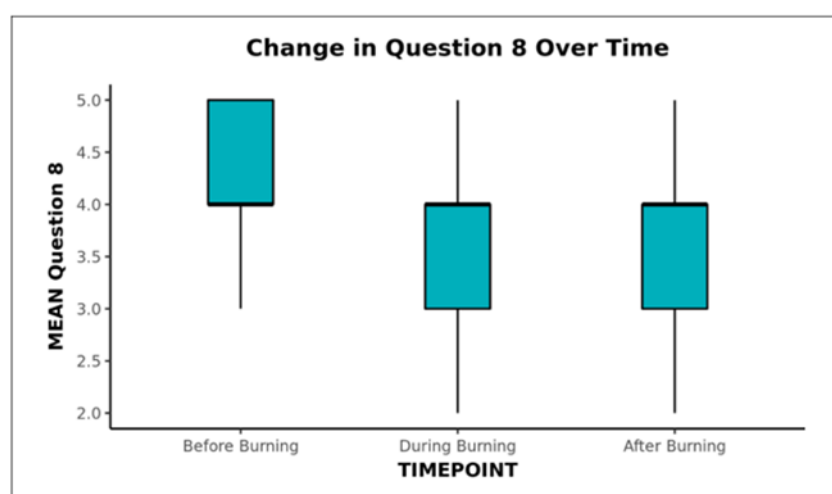
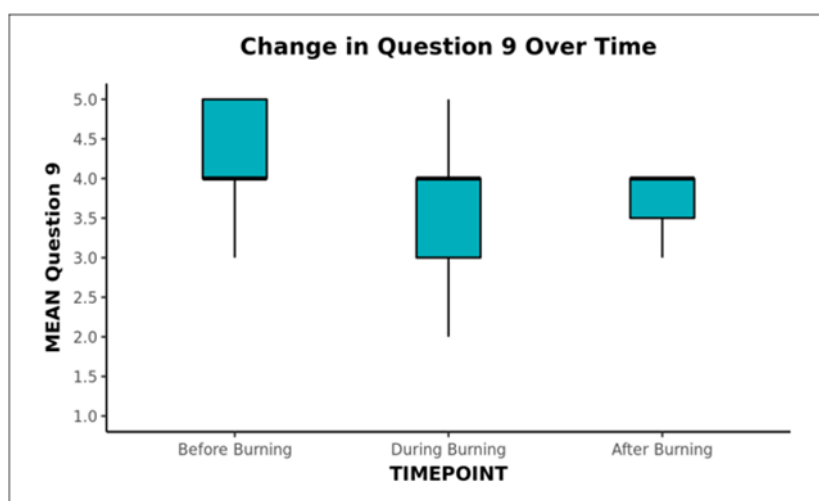


Figure 02: Box-and-Whisker plot depicts the distribution of Question 8 diagram depicting the change in over time.

Table 08: Change in question no 9 at 3 different time points

Timepoint	Question 9			Friedman Test	
	Mean (SD)	Median (IQR)	Range	χ^2	P Value
Before Burning	4.33 (0.67)	4.00 (1.00)	2.00 - 5.00	72.4	<0.001
During Burning	3.50 (0.81)	4.00 (1.00)	1.00 - 5.00		
After Burning	3.91 (0.64)	4.00 (0.50)	3.00 - 5.00		

The mean Question 9 decreased from a maximum of 4.33 at the before burning timepoint to a minimum of 3.50 at the during burning timepoint. This change was statistically significant (Friedman Test: $\chi^2 = 72.4$, $p = <0.001$)”.

**Figure 03:** Box-and-Whisker plot depicts the distribution of Question 9 diagram depicting the change in over time.**Table 09:** Change in question no 12 at 3 different time points

Timepoint	Question 12			Friedman Test	
	Mean (SD)	Median (IQR)	Range	χ^2	P Value
Before Burning	2.81 (1.06)	2.00 (1.00)	2.00 - 5.00	101.5	<0.001
During Burning	3.74 (0.67)	4.00 (1.00)	2.00 - 5.00		
After Burning	4.22 (0.63)	4.00 (1.00)	3.00 - 5.00		

“The Box-and-Whisker plot depicts the mean Question 12 increased from a minimum of 2.81 at the Before Burning timepoint to a maximum of 4.22 at the After Burning timepoint. This change was statistically significant (Friedman Test: $\chi^2 = 101.5$, $p = <0.001$)”.

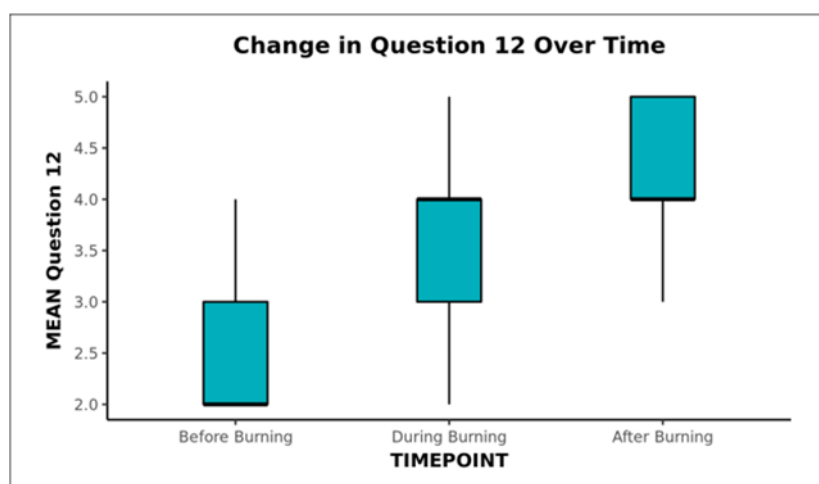


Figure 04: Box-and-Whisker plot depicts the distribution of Question 12 diagram depicting the change in over time.

Table 09: Change in question no 13 at 3 different time points

Timepoint	Question 13			Friedman Test	
	Mean (SD)	Median (IQR)	Range	χ^2	P Value
Before Burning	3.94 (1.01)	4.00 (2.00)	1.00 - 5.00	2.7	0.253
During Burning	3.80 (0.63)	4.00 (1.00)	3.00 - 5.00		
After Burning	3.92 (0.55)	4.00 (0.00)	3.00 - 5.00		

The mean Question 13 decreased from a maximum of 3.94 at the Before Burning timepoint to a minimum of 3.80 at the During Burning timepoint, and then increased to 3.92 at the After Burning timepoint. This change was not statistically significant (Friedman Test: $\chi^2 = 2.7$, $p = 0.253$).

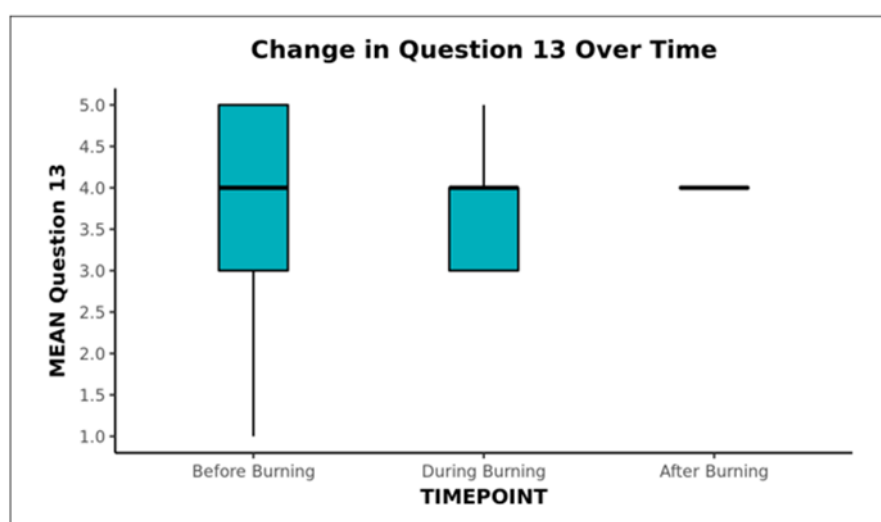
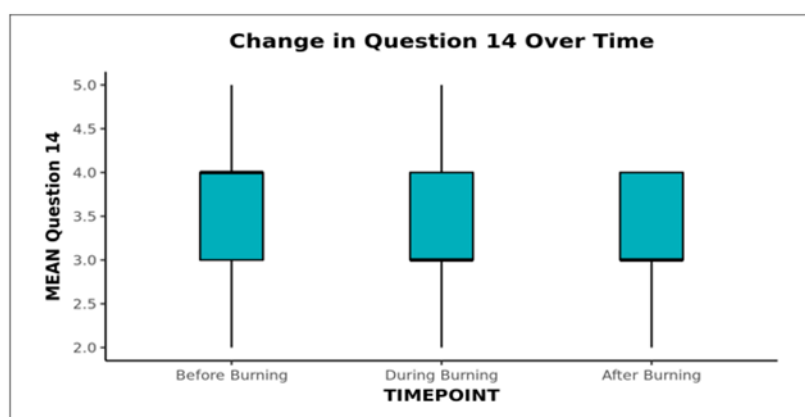


Figure 05: Box-and-Whisker plot depicts the distribution of Question 13 diagram depicting the change over time.

Table 10: Change in question no 14 at 3 different time points

Timepoint	Question 14			Friedman Test	
	Mean (SD)	Median (IQR)	Range	χ^2	P Value
Before Burning	3.67 (0.91)	4.00 (1.00)	2.00 - 5.00	13.7	0.001
During Burning	3.34 (0.73)	3.00 (1.00)	2.00 - 5.00		
After Burning	3.43 (0.51)	3.00 (1.00)	2.00 - 4.00		

The mean Question 14 decreased from a maximum of 3.67 at the Before Burning timepoint to a minimum of 3.34 at the During Burning timepoint, and then increased to 3.43 at the After Burning timepoint. This change was statistically significant (Friedman Test: $\chi^2 = 13.7$, $p = 0.001$).

**Figure 06:** Box-and-Whisker plot depicts the distribution of Question 14 diagram depicting the change in over time.**Table 11:** Change in question no 23 at 3 different time points

Timepoint	Question 23			Friedman Test	
	Mean (SD)	Median (IQR)	Range	χ^2	P Value
Before Burning	3.81 (1.19)	4.00 (2.00)	2.00 - 5.00	55.3	<0.001
During Burning	3.55 (0.52)	4.00 (1.00)	2.00 - 5.00		
After Burning	2.87 (0.49)	3.00 (0.00)	2.00 - 4.00		

The mean Question 23 increased from 3.81 at Before Burning timepoint to a minimum of 2.87 at the after Burning timepoint. This change was statistically significant (Friedman Test: $\chi^2 = 55.3$, $p = <0.001$).

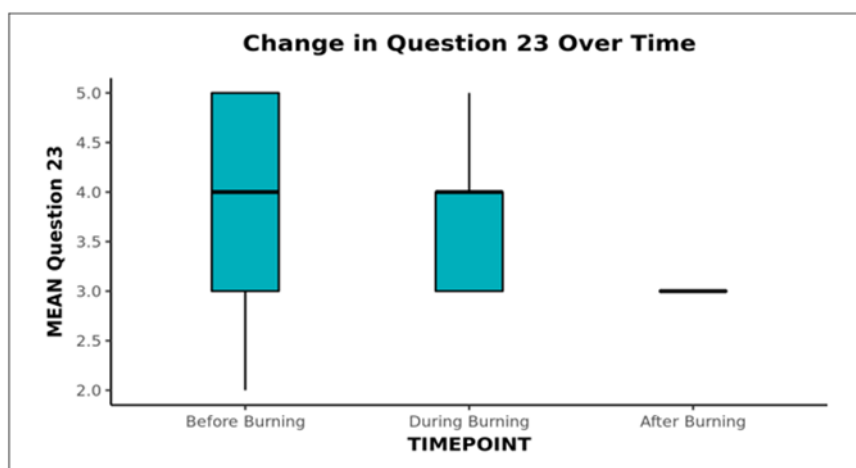


Figure 07: Box-and-Whisker plot depicts the distribution of Question 23 diagram depicting the change in over time.

Table 12: Change in question no 24 at 3 different time points

Timepoint	Question 24			Friedman Test	
	Mean (SD)	Median (IQR)	Range	χ^2	P Value
Before Burning	2.40 (0.75)	2.00 (1.00)	2.00 - 5.00	105.5	<0.001
During Burning	1.73 (0.61)	2.00 (1.00)	1.00 - 3.00		
After Burning	2.70 (0.46)	3.00 (1.00)	2.00 - 3.00		

The mean Question 24 decreased from 2.40 at the Before Burning timepoint to a minimum of 1.73 at the During Burning timepoint, and then increased to 2.70 at the After Burning timepoint. This change was statistically significant (Friedman Test: $\chi^2 = 105.5$, $p = <0.001$)

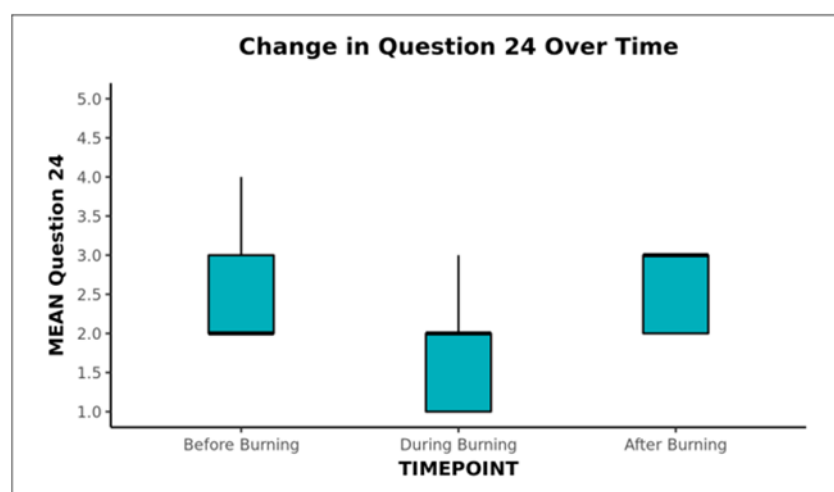
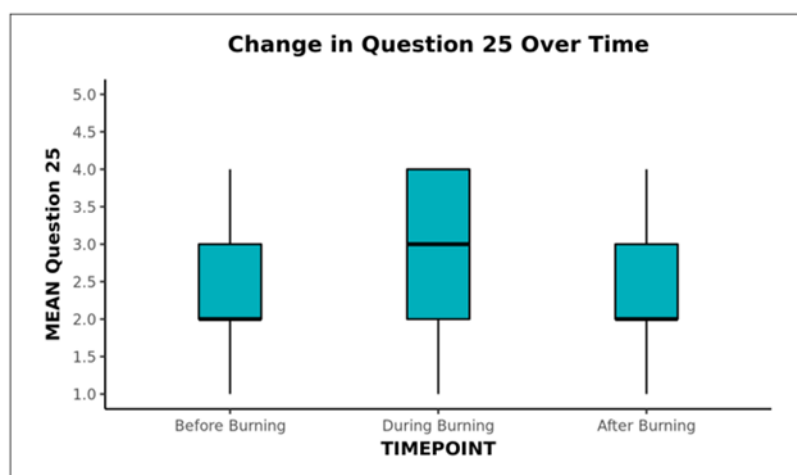


Figure 08: Box-and-Whisker plot depicts the distribution of Question 24 diagram depicting the change in over time.

Table 13: Change in question no 25 at 3 different time points

Timepoint	Question 25			Friedman Test	
	Mean (SD)	Median (IQR)	Range	χ^2	P Value
Before Burning	2.41 (0.98)	2.00 (1.00)	1.00 - 5.00	31.7	<0.001
During Burning	2.92 (0.90)	3.00 (2.00)	1.00 - 4.00		
After Burning	2.31 (0.69)	2.00 (1.00)	1.00 - 4.00		

The mean Question 25 increased from 2.41 at the Before Burning timepoint to a maximum of 2.92 at the During Burning timepoint, and then decreased to 2.31 at the After Burning timepoint. This change was statistically significant (Friedman Test: $\chi^2 = 31.7$, $p = <0.001$).

**Figure 09:** Box-and-Whisker plot depicts the distribution of Question 25 diagram depicting the change in over time.**Table 14:** Comparison of the 3 subgroups of the variable period in terms of PM_{2.5}

PM _{2.5}	Period			Kruskal Wallis Test	
	Before Burning	During Burning	After Burning	χ ²	p value
Mean (SD)	59.91 (34.59)	83.78 (30.04)	63.55 (30.61)	30.67	<0.001
Median (IQR)	65.01 (29.69-82)	82.1 (61.84-102.74)	56.83 (40.92-84.07)	0	
Range	4.76 - 184.2	18.4 - 151.86	11.77 - 163.22		
Pairwise Comparison of Subcategories of Period				Adjusted P Value	
After Burning - Before Burning				0.896	
After Burning - During Burning				<0.001	
Before Burning - During Burning				<0.001	

To gain a better understanding of seasonal variations in the ambient air quality, this study analyzed data from a Continuous Ambient Air Quality Monitoring Station (CAAQMS) installed at RIMT University in Mandi Gobindgarh, Punjab. The Figure depicts the concentrations of various air pollutants such as PM_{2.5} and PM₁₀. The data is time resolved and has a frequency of 15 minutes “3 month each for before during and after burning respectively have been considered. July, August and September are considered as

before burning whereas October, November, December is considered as burning phase and January, February and March is considered as post burning phase". Since the variable $PM_{2.5}$ was not normally distributed in the 3 sub-groups across the three time periods, on applying non-parametric tests (Kruskal Wallis Test), there was a significant difference between the 3 groups in terms of $PM_{2.5}$ ($\chi^2 = 30.670$, $p = <0.001$), with the median $PM_{2.5}$ being highest in the period for during burning group. But this had only Strength of Association (Kendall's Tau) = 0.03 (Little/No Association).

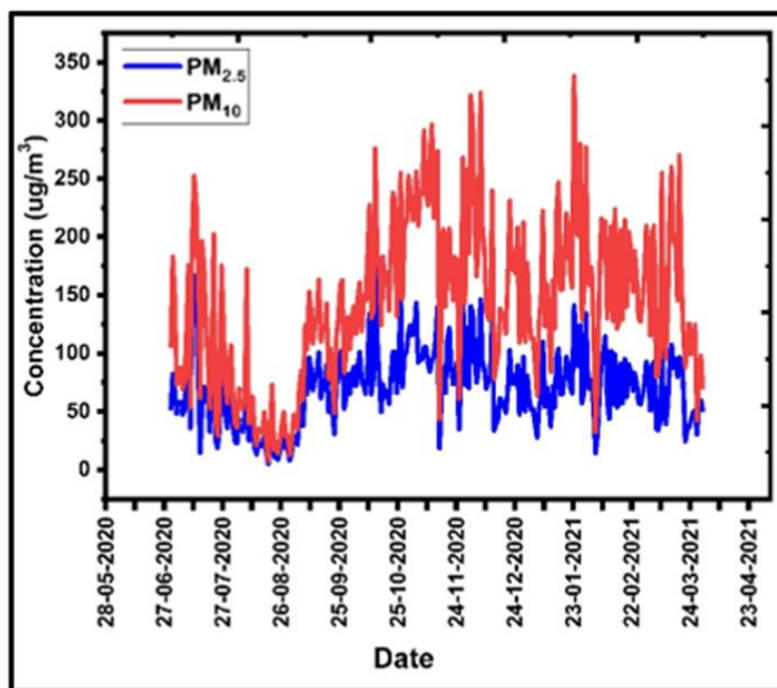


Figure 10: Trend of air pollution in Khera during the study period

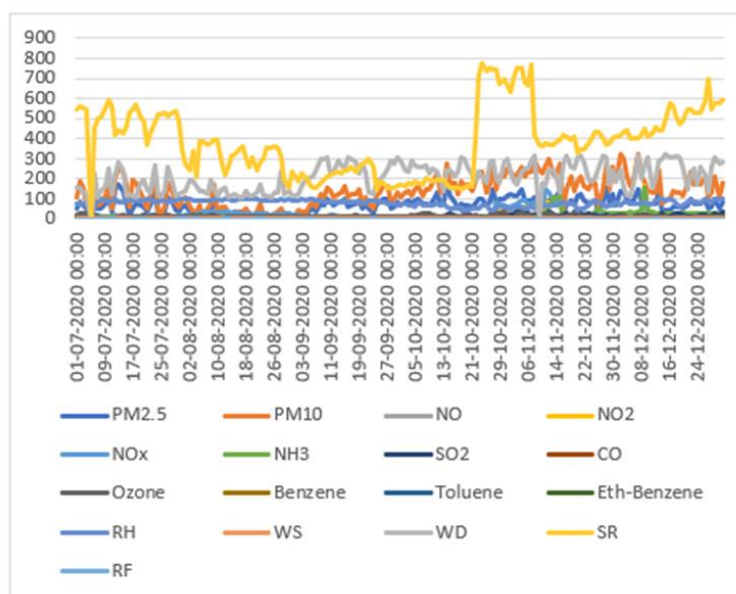


Figure 11: Shows the Visible Infrared Imaging Radiometer Suite (VIIRS) 375m thermal nomalies/active fire over state of Punjab data and Ambient Air Quality Data year 2020.

The fire count data were derived from the VIIRS 375 m FIRMS standard active fire product, which was acquired using the VIIRS sensor aboard the joint NASA/NOAA Suomi-National Polar-orbiting (Suomi NPP) satellite <https://firms.modaps.eosdis.nasa.gov/>. VIIRS has a 3040-kilometer swath and provides complete worldwide coverage, while the method used to estimate fires utilizes all five 375-meter channels. Due to the increased spatial resolution of the 375m datasets, which enables the detection of a greater number of flames of varying severity, they are widely employed in fire control and other research applications (NASA Earthdata). Due to its higher spatial resolution than the MODIS sensor, it exhibits a faster response time, allowing for the detection of even minor fires. Due to the increased geographic resolution of VIIRS fire datasets, they have been used in a number of air pollution research investigations. For additional analyses, the fire count data were processed in QGIS.

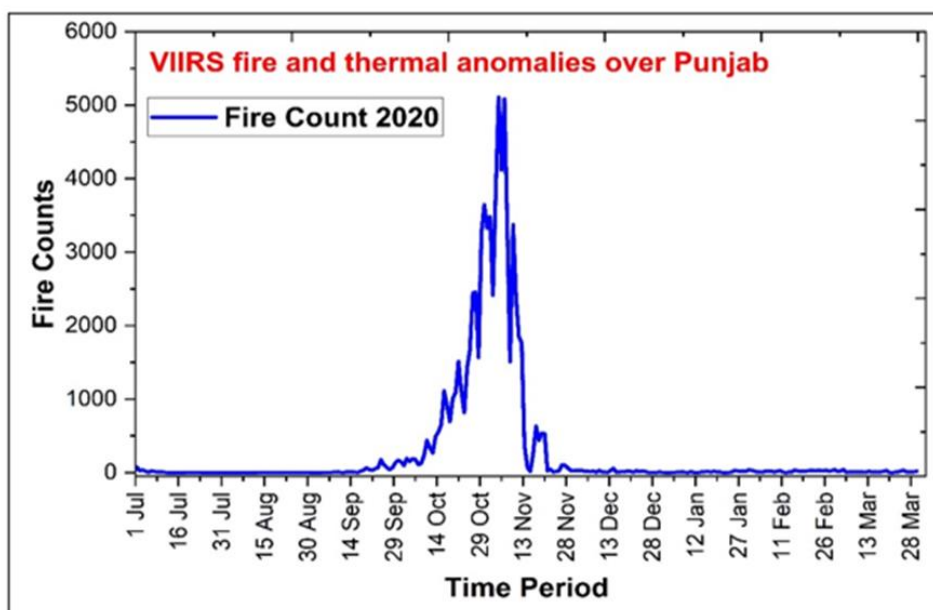


Figure 12: Visible Infrared Imaging Radiometer Suite (VIIRS) 375 m fire and thermal anomalies over Punjab from July 2020 to March 2021

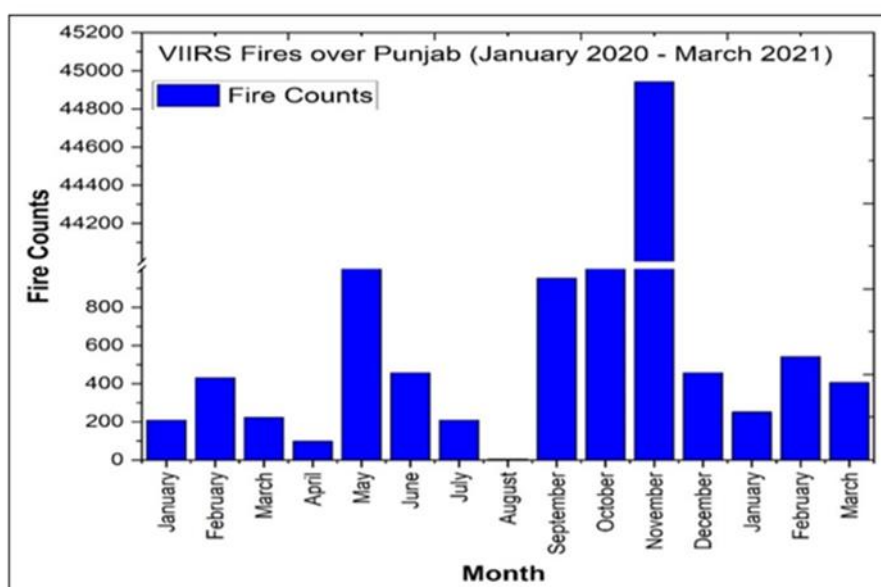


Figure 13: Visible Infrared Imaging Radiometer Suite (VIIRS) 375 m fires over Punjab

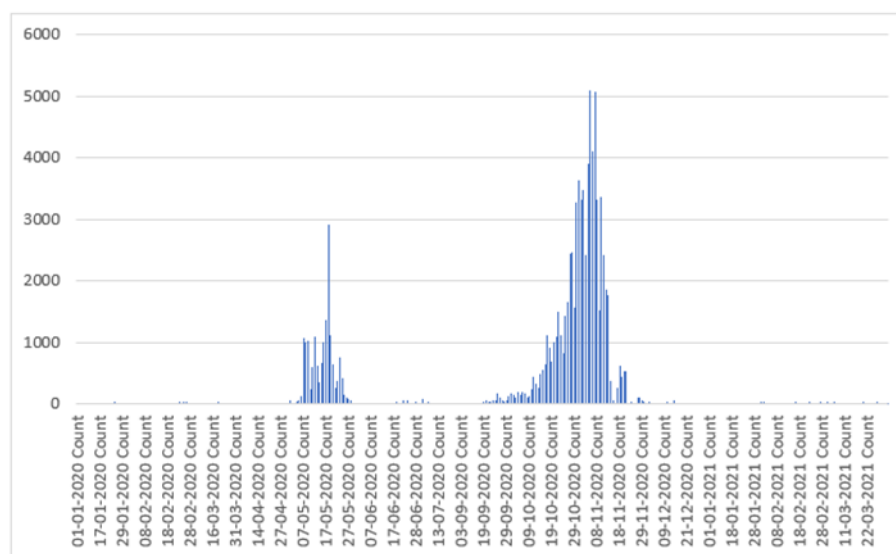


Figure 14: Visible Infrared Imaging Radiometer Suite (VIIRS) 375 m thermal anomalies / active fire Fire Count

DISCUSSION

Air pollution is one of the major health risks for humans and environment, with India having some of the worst levels among other countries [14]. Stubble burning is one of the major contributors of air pollution in several continents of the world and is placed at 3rd position after “industrial and vehicular emissions” [15]. “As per the Yadav and Devi, on a global platform, stubble burning constitutes around one-fourth of the total biomass burning (including forest fires) [16]. As per Sikarwar and Rani, most of the cities hit by the stubble on the national list fall under North-India, especially the state of Uttar Pradesh [17]. Haryana and Punjab are two of the major agricultural states contributing 48% to rice stubble as per Indian Agricultural Research Institute (IARI)” [18]. Media reports tend to identify stubble burning in Punjab and Haryana as a major contributor to Delhi’s air pollution at the onset of winter every year. In Punjab, rice and wheat present around 85.91% of the total cultivable output as it is regarded as India’s Breadbasket. “Rice is usually planted in the summer season, around May/June, and harvested around October/November. Wheat is normally planted during winter, mostly in December and harvested during the summer of the subsequent year, around April/May. The stubble burning is performed immediately after harvest in every season.” “The farmer's point of view includes burning the crop after harvest to prepare the farmland for the next cultivation. Another reason for the deterioration of air quality during harvesting time is that the great Indian festival “Diwali” which coincide with the stubble burning periods, resulting in further deterioration of the air quality”. In our study, the mean age among participants was 41.99 ± 11.18 and the Male: Female ratio was 31.5:68.5 [19]. The mean years of education among participants were 3.52 ± 1.48 . and 27 (21.8%) were unemployed as head of the family. The probable reason for majority cases being female is that the area where the study was conducted had more females. During the daytime, the female population is usually available at the household. 34.7% were workers at a government or private setup, 21.8% were unemployed, 15.3% were unskilled laborers, 12.9% business, 10.5% housewives, and only 1.6% were agriculturist. 20.2% of the participants had low socioeconomic status. Whereas 79.8% of the participants had middle socioeconomic status. None of them had high status. The harmful effects of exposure to stubble burning include skin and eyes irritation to severe cardiovascular, respiratory, and neurological diseases,

that might prove life-threatening to the farmers and their families [20]. “According to an author Fine particulate matter (PM_{2.5}) has much worse effects on human beings than the larger size particles as it can penetrate through the trachea into the lungs and to circulation”. In our study, 13.7% of the participants had a symptom of wheezing, 14.5% of the participants had a symptom of breathlessness/chest tightness, 33.9% of the participants had symptom of shortness of breath after exertion, 22.6% of the participants had symptom of shortness of breath without exertion, 21.0% of the participants had symptom of getting up at night due to breathlessness, 14.5% of the participants had symptom of getting up at night due to cough, 19.4% of the participants had symptom of cough first thing in morning, 17.7% of the participants had symptom of expectoration first thing in morning, 16.9% of the participants had symptom of expectoration most morning for 3 months/year [21]. 4.8% of participants had asthma. This indicates that stubble burning has several minor to major impacts on the respiratory system of the human being. Several cases also had symptoms indicating COPD and Asthma. 66.7% of the participants had Smoking Status: I Still Smoke, whereas 33.3% of the participants had Smoking Status: I Have Left Smoking for more than a year [22]. The majority smoked in the form of Zarda. Also, 33.1% had skin rashes, 14.5% had symptoms such as sneezing and running nose and 27.4% had eye irritation. This indicates the involvement of several systems of the human body due to burning. “Apart from the respiratory system, stubble burning also impacts tourism and economic development. A survey in Delhi NCR area in 2018 suggested that tourism has decreased by about 25-30 % as a result of air pollution” [23]. Similarly, WHO BREF Questionnaire was administered to the 120 participants, out of which 110 were self-administrated and 10 were interviewer-assisted [24]. “WHOQOL BREF consists of 4 domains. These are physical health, psychological aspect, social relationship and environment. Domain 4 deals with environment issue i.e. Q8 + Q9 + Q12 + Q13 + Q14 + Q23 + Q24 + Q25 of BREF Questionnaire. This tool is WHO's initiative to develop a quality-of-life assessment. The WHOQOL-BREF contains a total of 26 questions [25]. For epidemiological research, the WHOQOL assessment allows detailed quality of life data to be gathered on a particular population, facilitating the understanding of diseases and for developing treatment methods. [26]” The study was categorized in 3 groups: before burning, during, and after burning. “Non-parametric tests (Friedman test) were used to make a statistical inference as data were not normally distributed”. All the domains had statistically significant changes $p < 0.05$. Details have been explained in the result section. This indicates that quality of life also changes before, during and after the burning period related to environmental consequences. “The annual population-weighted mean exposure to ambient particulate matter PM_{2.5} in India was 89.9 $\mu\text{g}/\text{m}^3$ in 2017. Most states, and 76.8% of the population of India, were exposed to annual population-weighted mean PM_{2.5} greater than 40 $\mu\text{g}/\text{m}^3$, which is the limit recommended by the National Ambient Air Quality Standards in India. Delhi had the highest annual population-weighted mean PM_{2.5} in 2017, followed by Uttar Pradesh, then Bihar, and Haryana in North India, all with mean values greater than 125 $\mu\text{g}/\text{m}^3$ [27].” In our study, 3 months each for before, during and after burning respectively have been considered. July, August and September were considered as before burning whereas October, November, December were considered as the burning phase and January, February and March were considered as post-burning phase. “The variable PM_{2.5} was not normally distributed in the 3 subgroups of the variable period [28]. Thus, non-parametric tests (Kruskal Wallis Test) were used to make group comparisons. There was a significant difference between the 3 groups in terms of PM_{2.5} ($\chi^2 = 30.670$, $p = < 0.001$), with the median PM_{2.5} being highest in the period for during burning group”. A study suggested that small particles (PM_{2.5} and PM₁₀) —that makes “maximum smoke produced by burning crops were associated with decreases in lung function compared to suspended particulate matter (SPM), which can contain particles 100 μm or larger”. ³² The study published in Lancet 2019 suggested that “the average life expectancy in 2017 would have been higher by 1.7 years (1.6–1.9), with this increase overcoming 2 years in the states of Rajasthan, Uttar Pradesh, and Haryana.” “Household air pollution is mainly caused by the burning of fuels that are solid for cooking” and also use of “wood,

dung, agricultural residues, coal, and charcoal" [29]. Stubble burning has a significant source of gaseous pollutants such as "carbon dioxide (CO₂), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), and methane (CH₄) as well as particulate matters (PM₁₀ and PM_{2.5})" that causes life-threatening damage to the health of human beings and environment [30]. The rise in stubble burning during the pandemic published by the Press Trust of India, New Delhi in a local level newspaper stated that "Unavailability of laborers - many returned to their native states due to the COVID-19 pandemic - is also a reason why farmers are burning stubble to clear the fields quickly," as per "Harinder Singh Lakhwal, the general secretary of the Bharatiya Kisan Union, Punjab". He also stated that "anger over farm bills is one of the major reasons". "The crop stubbles (if managed properly) could provide immense economic benefits to the farmers and protect the environment from the severe pollution". Although State Pollution Control Boards have banned this practice "since 2005, satellite fire hotspot data have shown an increased occurrence of agricultural fires through the subsequent years" [31]. Also, collaboration and effective communication between the neighboring states and national governments is necessary. Formulating plans and policies and their effective enforcement and follow-up should be exhibited by government organizations [32].

4. CONCLUSIONS

An overwhelming ideology has been created among scientists in the last two decades as the world has entered a devastating era of rapid global climate change. The majority linked with greenhouse gas emissions from human behavior, which impact agriculture in different ways, including extreme weather. The primary aim of the present study is to "assess changes in respiratory function and quality of life of people living in the rural community of Punjab, India and to measure PM_{2.5} level in ambient air" during the study period. "The study was prospective observational. The participants were selected and were followed up after approval by Institutional Ethics Committee. Written informed consent from the participant was taken, study included "WHO-BREF questionnaire which is a survey of quality of life, monitoring of PM_{2.5} level in ambient air using official data from "Punjab Pollution Control Board (Notification No. 6186-BR II (4) 75/24146 30.07.1975)" ¹⁷ socio-demographic profile of the participants, their Respiratory symptoms if any present was noted." The mean age among participants was 41.99 ± 11.18. and Male: Female 31.5%:68.5% The mean years of education among participants were 3.52 ± 1.48 and 27 (21.8%) were unemployed as head of the family. 13.7% of the participants had a symptom of wheezing: while 86.3% of the participant didn't have it. 14.5% of the participants had symptom of Breathlessness/Chest Tightness in the morning, whereas 85.5% had no symptoms. The mean duration of wheezing and tightness of the chest was 2.89+/-3.66. and 1.89+/-2.61, respectively, while the mean duration of shortness breath after exertion was 2.10 ± 2.37. Respectively, 13.7-24.2% of them had several respiratory symptoms mentioned in the result and discussion. Similarly, WHO BREF Questionnaire was administered to the 120 participants, out of which 110 were self-administrated and 10 were interviewer-assisted. Domain 4 deals with environment issue i.e., Q8 + Q9 + Q12 + Q13 + Q14 + Q23 + Q24 + Q25 of BREF Questionnaire. On-parametric tests (Friedman test) were used to make a statistical inference as data were not normally distributed, which were statistically significant (p<0.05) 3 months each for before, during and after burning respectively have been considered. July, August, and September were considered before burning whereas October, November, December were considered the burning phase and January, February and March were considered the post burning phase. There was a significant difference between the 3 groups in terms of PM_{2.5} (p <0.05) with the median PM_{2.5} being highest in the period: during burning group.

5. RECOMMENDATIONS

- Some of the alternative management practices include the incorporation of the stubble into the soil, use of stubble as fuel in power plants, use as raw material for pulp and paper industries, or as biomass for biofuel production.
- It can also be used to generate compost and biochar through pyrolysis, or as a blend for the production of cement and bricks, animal feeds, for making cattle sheds or rural houses roofs.
- Employment of agricultural machines like happy seeder, rotavator, zero till seed drill, paddy chopper and reaper binder for effective residue management.
- Scientists have also indicated alternative methods of management of stubble such as raw material for alcohol refineries, mushroom farming fodders, or as fuel for gasifying boilers.
- Most of the farmers in North India are not aware of the prolific alternatives for managing stubble and, therefore, consider burning as the best option. Thus, an extensive and scientific awareness program is necessary to enlighten the farmers.

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