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**Research Article**

# Study of Four PUSA Varieties of Paddy Husk and the Effects of Its Burning on the Environment

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**ABSTRACT**

Green revolution belt in the Northern India includes the state of Haryana. It's a major producer of Paddy in India as 18 districts are involved in Paddy cultivation. Out of these 7 districts are having very good paddy cultivation yielding more than 2500kg per hectare. In these districts the farmers are utilising the fields all through the year and for that matter are using all types of machinery to increase the speed of harvesting. Hence, they are using Combine harvesters to harvest the crops of Paddy. This increases the speed of harvesting at a low cost but brings with it another problem which is it cuts the crops at a height of about 10cm from the ground. This stubble of paddy which is left in the field is a major issue as the farmers are burning and removing the stubble from their fields after harvesting the crop.

Burning of paddy stubble and other agro wastes has resulted in air pollution problems which are not only in Haryana but has also spread to Delhi particularly which results in a smog condition in the cold winter months.

Research is done in the SRM University Sonepat district of Haryana from the year 2023-2025 by burning the stubble and straw of four different varieties of paddy which are majorly grown in Haryana. Then the gaseous pollutants are tested along with suspended particles which are released by burning of the stubble and straw of paddy. The data is compared with the CPCB data to find out the consistency in the results. Also, the months in which there is more pollution is found by comparison of the results with the CPCB data.

This study is to understand the pollutants released by burning of stubble of four different varieties of Paddy which is resulting in adverse effects on the population. It is found that Carbon monoxide, Sulphur dioxide, Nitrogen dioxide, Carbon dioxide and particulate matter are released in considerable amounts but they do not vary much based on variety. Also physical parameters of the paddy husk is studied which shows similar results.

**Keywords:** Carbon Dioxide, Carbon Monoxide, Sulphur, Volatile Organic Compounds, Particulate Matter, Central Pollution Control Board (CPCB)

## INTRODUCTION

India is a country based on Agrarian Economy. Agriculture is the backbone of our country. Farming has grown tremendously with Green Revolution in the states of Punjab, Haryana, Delhi and Western U.P. and food is now available to most of the population in India. But with hybrid seeds and irrigation facilities being available throughout the year the farmers in this belt of India are cultivating their land all through the year and are not leaving the land uncultivated. This continuous cropping has started practices like –Stubble Burning to clear the land within a day and with no additional labour cost. But it has led to several problems which includes loss of plant nutrients, health problems, death of microbes in the soil, air pollution, global warming, smog and even reported accidents and deaths.Paddy stubble is rich in nutrients which is being burnt by the farmers of Northern Paddy cultivating states of Punjab, Haryana, and Western U.P. of India, since the labour cost has risen, and it takes about a month or two to remove the stubble. Mechanisation has brought with it the ill effect of leaving behind the crop stubble on the ground which has to be removed either by hand or some machine. To avoid all these problems the farmers of India have resorted to burning of the stubble in the farm. This has led to widescale pollution and health risks to the people in the NCR and in the national capital N. Delhi particularly in the months when the stubble is being burnt. To

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comprehend paddy stubble content, characteristics, and possible uses or disposal techniques, physico-chemical characterization is crucial. This characterization offers useful data for energy production, composting, recycling, and other applications. (Kiran et al., 2021).

The chemical composition of rice husks is 38% cellulose and 18% hemicellulose and 22% lignin, and contains a large amount of silica, which makes it a good basis for biochar production. (Saeed et al., 2021)

Although rice straw has many benefits over other feedstocks in producing biogas, including non-interference with food supply, low price, and relatively high biogas production, direct utilization in anaerobic digestion is limited (Dahadha et al. 2017). Recalcitrant lignocellulosic structure makes rice straw difficult to be broken down by microorganisms. This slows hydrolysis, the first rate-limiting step of the anaerobic digestion process, which subsequently leads to inefficient biogas production. (Alengebawy et al., 2023)

Traditionally, biogas production from rice straw is based on solid-state anaerobic digestion, which is operated at a total solid content of more than 15%. Solid-state anaerobic digestion has various problems, such as inefficient biogas production, hindered mass transfer between lignocellulosic biomass and microbes, process instability, inhibition from intermediate products such as ammonia and volatile fatty acids, and problems in end-product management (Yang et al. 2015).

Moreover, Paddy stubble and husk are difficult to degrade due to its high specific area and porous structure. (Severo et al., 2020a)

Rice straw is characterized by a slow decomposition rate; thus, some farmers avoid rice straw soil incorporation especially in intensive cropping systems with 3 weeks interlude. (Douthwaite et al., 2020)

In terms of total carbon dioxide equivalent ($CO_2$-eq) per ha converted from $CH_4$ and $N_2O$, recent research at IRRI showed that rice straw soil incorporation emitted about 3500 to 4500 kg $CO_2$-eq $ha^{-1}$ (Rosamanta 2017) which is about 1.5–2.0 times higher than when rice straw was removed.

In the present modern civilization, all along with mechanized agriculture, farmers all over the world in general and states of Punjab and Haryana in India in particular complain that rice straw has become a huge problem for them because they follow mechanized agriculture, have shortage of labour, need fast clearance of their fields for next crop etc. When rice/wheat is harvested by a combine harvester it leaves a significant length of straw on the field. Moreover, both wheat and rice are long-duration crops and with a short period available between rice harvesting and wheat plantation, increasing labour cost and non-availability of any user-friendly and cost-effective technology to make the use of crop residue, burning of stubble seems the easiest and quickest way to get rid of rice straw to the farmers. In the absence of assured returns, farmers find stubble burning an economic way of managing the agro waste. (Verma, 2014)

Extensive stubble burning releases massive toxic air pollutants in the northern states of India (Kulkarni et al. 2020). The onset of winter and retreating monsoon (October to November) with northwest wind causes the spreading of such pollutants in the surrounding areas and degradation of air quality (Cusworth et al. 2018). India's capital Delhi and surrounding region (NCR) is landlocked by the surrounding states and the Hindu Kush Himalayan mountainous range bounds the entire region in the north. Such a landscape distribution and northwest wind transport the toxic air pollutants from the crop field of Haryana and Punjab to the NCR. In addition to the pollutants from stubble burning, the use of firecrackers during the festivals in October and November, fossil fuel burning, and industrial emissions degrade the air quality in the NCR (Kulkarni et al. 2020). More than 46 million population in Delhi and NCR experience severe air quality each year during the onset of winter, i.e., October and November (Census 2011). (Das et al., 2023)

Crop residue burning (CRB) contributes to high particulate matter (PM) concentration in ambient air in Delhi and NCR region. High PM2.5 concentration in ambient air poses adverse health effects to public. During CRB period, the mean daily PM2.5 concentrations increased almost four times (193-270 μg/m3) the ambient air quality standard for PM2.5 (60 μg/m3 ) adopted by India. On-field and off-field stubble management interventions should be encouraged to reduce the health effects in the farmers. (Central Pollution Control Board et al., 2021)

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Stubble burning has been reckoned among the major contributors of air pollution especially in South Asia. It is a significant source of gaseous pollutants such as, carbon dioxide ($CO_2$), carbon monoxide (CO), nitrogen oxides ($NO_x$), sulfur oxides ($SO_x$), and methane ($CH_4$) as well as particulate matters ($PM_{10}$ and $PM_{2.5}$) causing serious damage to human health and the environment.About 84 Mt (23.86%) of the stubble is burnt on-field each year immediately after harvest. The disastrous haze observed over India during the winter season has been linked to stubble burning as it coincides with the burning periods (October-November). During this time, most Indian cities, especially within the National Capital Region (NCR) experience harsh pollution often reaching the severe levels of the air quality index (AQI). (Abdurrahman et al., 2020)

Burning of agricultural crop residue to clear fields is a major contributor to air pollution. When rice farmers in north-western India burn their fields, fine particulate matter (PM2.5) concentrations in Delhi, the highly populated capital city located downwind of burning areas, spike to about 20 times beyond the World Health Organization's threshold for safe air. Children are particularly susceptible to the health effects of crop burning. (Chakrabarti et al., 2019)

There is a lack of market demand for the stubble, which attracts the farmers to opt for Kharif crop residue burning to prepare the land for the successive Rabi cropping in November (Singh et al. 2021). Such biomass burning emits particulate matter (PM) and various gaseous compounds as Carbon dioxide (CO2), Carbon monoxide (CO), Sulphur dioxide (SO2), Nitrogen dioxide (NO2), and various volatile organic compounds (VOCs), etc. (Das et al., 2023b) Solutions to eliminate crop burning exist but require further investments. Reducing crop burning would benefit human health.

## OBJECTIVES

1. Physical characterization of straw obtained from four different varieties of Paddy.
2. Chemical Analysis of paddy straw.
3.Studying the heavy metals released by burning paddy straw.
3. Understanding the gas characteristics of burning paddy straw.

## STUDY AREA

Haryana has a total area of 4.421 million hectares with a population of 25.3 million. It is situated between 27°39' and 30°35' north latitude and 74°28' and 77°36' east longitude. Haryana is also one of South Asia's most economically developed areas, with its agricultural and manufacturing industries growing steadily since the 1970s. Despite recent industrial expansion, Haryana remains predominantly an agricultural state. Approximately 70% of inhabitants are involved in agriculture. Wheat and rice are the main crops farmed here. Haryana produces all its own food and is the second largest contributor to India's central pool of food grains. Haryana's principal crops are wheat, rice, sugarcane, cotton, oilseeds, pulses, barley, maize, and millet.

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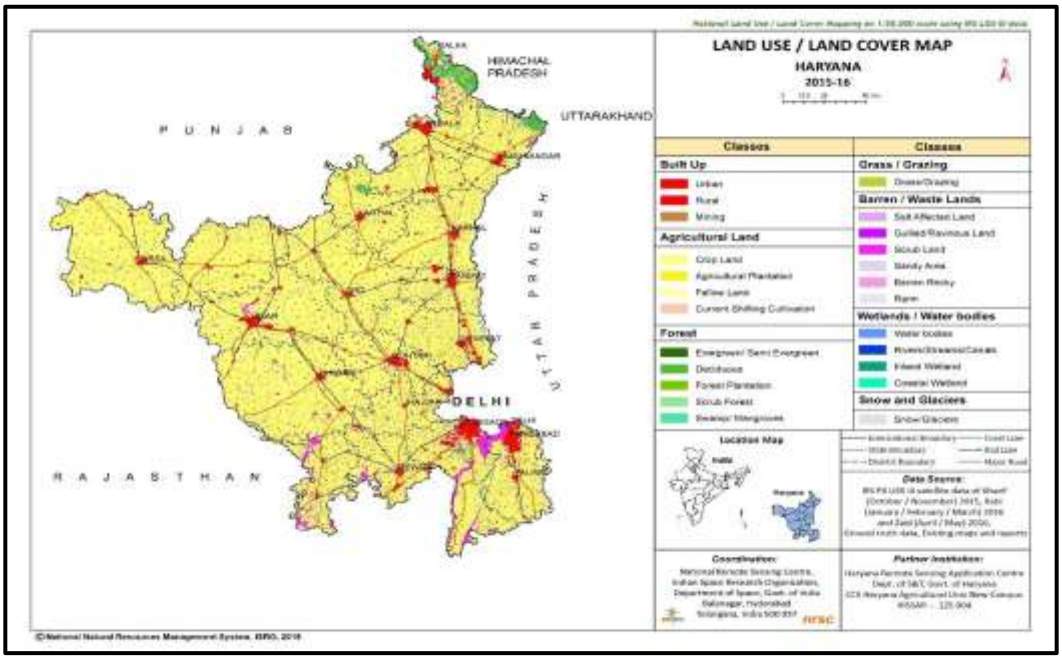
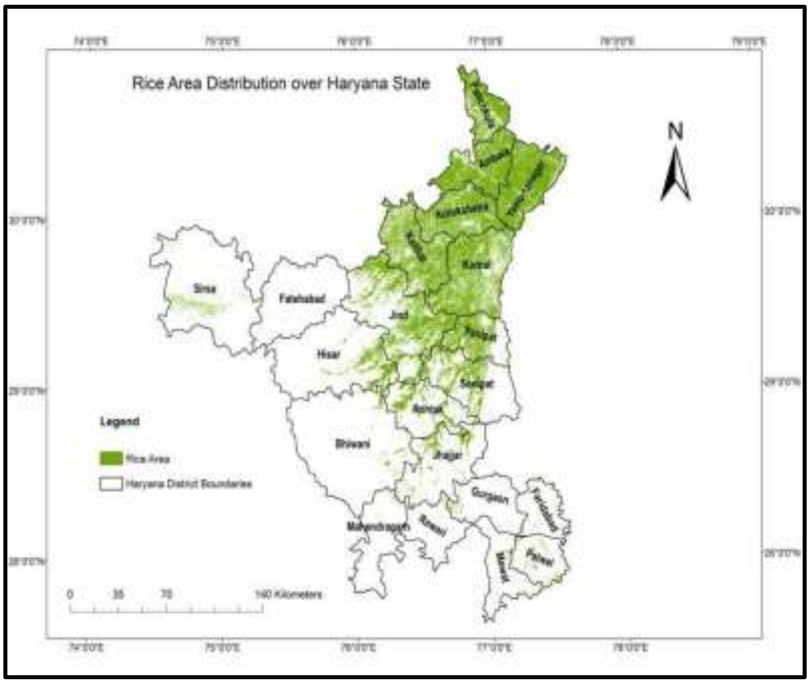



*1 Map Source: Bhuvan*




The area of research is in the state of Haryana which covers five districts which are major producers of paddy. -

1. Kurukshetra
2. Karnal
3. Kaithal
4. Panipat
5. Sonipat

## MATERIALS AND METHODS

In order to characterize paddy stubble physico-chemically, the following are the essential stages and variables:

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### 4.1. Sample Collection

Samples of paddy stubble is collected from the 5 districts of Haryana which are based on random sampling technique. The five districts are chosen based on the productivity of Paddy in these districts.

### 4.2. Sample Preparation for testing-

Sample is grounded and homogenized for ensuring consistency in analysis.

The stubble collected was checked first for the sample weight. Then it was put through oven to get the actual weight of the stubble.

### 4.3. Physical Properties testing-

The size range of particles contained in the trash can be understood by analysing the particle size distribution using methods such as sifting or laser diffraction.

*4.3.1 Bulk Density:*

The bulk density is determined of the waste material to evaluate its packing properties. Bulk density was calculated by weighing the material and using the formula of (Grossman and Reinsch, 2002) as

$$\text{Bulk Density kg/m}^3 = \frac{\text{Dry weight of mix}}{\text{Volume of mix}}$$

4.3.2Porosity is computed, a property that represents the volume of vacant spaces present in the material. Porosity is calculated by taking 10mg stubble powder in 15 ml water and leaving it for 24hrs. in water. Then finding the difference in water from the initial amount taken.

4.3.3True density is the actual solid devoid of all spaces. Its ratio of given mass of a powder and its true volume. Its calculated as –

$$\text{True density} = \text{Weight of Powder} / \text{Volume of liquid displaced by the powder}$$

Moisture content of the sample is tested by oven drying at a specific temperature until a constant weight is achieved. This gives the dry weight of the sample.

The colour and odour are tested by observation of the paddy stubble as it determines its reuse and recycling potential. This is important if it is used for manufacturing of plates, cutlery, bags, or fabrics.

## CHEMICAL ANALYSIS OF STUBBLE

The elemental analysis of stubble is done to determine elemental composition which includes -Carbon content, Nitrogen, Phosphorus and Potassium content.

### 5.1. Determination of Organic Carbon and Organic Matter in the Sample

1 N solution of $K_2Cr_2O_7$ is made as 49.035gm of $K_2Cr_2O_7$ is dissolved in distilled water to make up 1 litre. Then 140gm of Ferrous Ammonium Sulphate (FAS) is dissolved in 0.5N $H_2SO_4$ and made up to 1 litre.

1gm air dried sample of stubble is passed through 425-micron sieve and the sieved component is collected in 500ml conical flask. 10ml potassium dichromate(1N) is added along with 20ml sulphuric acid which is then allowed to stand for 30minutes. Then 200ml distilled water is added and it is cooled at room temperature. 0.5 Ferrous Ammonium Sulphate is titrated until colour changes from blue to green.

Calculations-

a) Organic Carbon (%) = 0.03xNx10x(1-S/B)

N=Normality of sample
B=Blank burette reading
S=Sample burette reading

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b) Organic matter (%) =1.72x Organic Carbon

### 5.2. Determination of Potassium in the given sample-

1 gm of air-dried sample is taken in a conical flask. To this sample 100ml of 40% Ethyl Alcohol is added. After shaking it well 10 minutes waiting time is given. The sample is then filtered through filter paper (Whatman no.50). Wash the sample residue on the filter paper with absolute ethyl alcohol. Transfer the residue to beaker and add 100ml of ammonium acetate solution. Stir it and allow standing overnight. Filter the supernatant through filter paper and collect the filtrate. The total volume of sample extract is noted.

$$\text{Potassium(mg/l)} = A \times V/W \times 10000$$

Where, A= Potassium content of sample extract(mg/l)
V= Total volume of sample extract(ml)
W= Weight of air-dry sample/sediment taken for extraction

### 5.3. Determination of Mineralizable Nitrogen (Available nitrogen) by Kjeldahl's method

1gm sample is collected and digested in Kjeldahl flask with 0.5gm copper sulphate and 7gm potassium sulphate till colourless. Measure 20ml of 2% boric acid containing mixed indicator in 250ml conical flask and it is placed under receiver tube. The receiver tube is dipped in boric acid. The tap water is run through the condenser. Add 100ml of 2.5% NaOH solution and immediately attach to rubber stopper fitted in alkali trap. Switch the heaters on and continue distillation until about 100ml of distillate is collected. First remove conical flask containing distillate and then switch off the heater to avoid back suction. Titrate distillate against 0.02M $H_2SO_4$ taken in burette until pink colour starts appearing. Run a blank without sample. Carefully remove Kjeldahl flask after cooling and drain contents in sink.

$$\text{Available Nitrogen Content (mg/kg)} = \frac{(A-B) \times N \times 14 \times 1000}{\text{Wt. of sample}}$$

Were,
A = Volume of 0.02M $H_2SO_4$ used in titration against absorbed in boric acid.
B = Volume of 0.02M Sulphuric acid used in blank titration
1ml of 0.02 $H_2SO_4$ = 0.56mg N (1000 ml of 1M $H_2SO_4$ = 14g Nitrogen)

### 5.4. Determination of Phosphorus (Titrimetric Method)

5 gm of oven dried sample is taken in a silica crucible. It is heated on a Bunsen burner at a low flame until the substance is charred. Extract the ash with hot HNO3, filter and wash. Make the volume to 100ml.Take 50ml of the molybdate solution,10ml of Conc.HNO3 in two tubes. Add HNO3 first and then add molybdate solution. Stir the mixture gently and allow to stand overnight. Collect the canary yellow Ammonium phosphomolybdate by filtration over Whatman No.40 or 42 filter paper. Wash the precipitate first by decantation and twice with 2% HNO3 and then with KNO3 solution. Wash until the precipitate is acid free and test with a strip of blue litmus paper. Transfer the precipitate along with the filter paper to the original beaker and dissolve the yellow precipitate in measured volume of 0.1N NaOH solution, added in excess from a burette. Use the phenolphthalein as indicator and titrate the excess of NaOH with 0.1N HCl.

Calculations

The conversion factors are-

1ml of 0.1N NaOH = 0.0001351g P.
= 0.000309g P2O5

The Di phosphorus pentoxide content expressed as a percentage by mass, is equal to

$141{,}95 \times m_1 \times V_1 \times 100 = 3{,}207 \times V_1 \times m_1$

$4\,425{,}84\ V_0\, m_0\ \ V_0\, m_0$

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Where,
M0 is the mass, in grams, of the test potion.
M1 is the mass, in grams, of the precipitate.
V0 is the volume, in millilitres, of the aliquot portion taken from the extraction solution,
V1 is the volume, in millilitres, of the extraction solution.
141,95 is the relative molecular mass of Di phosphorus pentoxide
4 425,84 is twice the relative molecular mass of quinoline phosphomolybdate

### 5.5. Testing the burning behaviour of stubble

Burning behaviour of these samples are checked by burning the stubble in the flue Gas analyser. For performing the flue gas analysis, a probe is inserted into the flue of the furnace between the draft diverter and the heat exchanger. An electrochemical probe is used to do this analysis.

## RESULTS

### 6.1 Physical composition

*6.1.1 Table-Physical composition of paddy varieties*

| Paddy Variety | Moisture content (%) | True Density of stubble(kg/m3) | Bulk density of stubble (kg/m3) | Porosity of stubble (%) |
|---|---|---|---|---|
| **1121** | 11.5±0.265 | 727.62±0.174 | 374±2.16 | 48.51±0.245 |
| **1718** | 12.1±0.085 | 673.07±1.709 | 350±2.94 | 48±0.124 |
| **1509** | 11.1±0.052 | 683.62±0.645 | 352±2.49 | 48.51±0.230 |
| **Traditional Basmati** | 12.2±0.209 | 654.54±1.885 | 360±2.44 | 45±0.801 |

Based on Physical Composition-The moisture content is the highest in Traditional Basmati. True density of the stubble is highest in 1121 variety of Paddy, Bulk density is also highest in 1121 variety of stubble, porosity is same in 1121 and 1509 varieties of paddy.

### 6.2 Table-Chemical Composition of Paddy varieties

| S. No. | Chemical Characterization (% by mass) | Test Method | Paddy Variety | | | |
|---|---|---|---|---|---|---|
| | | | **1121 Var** | **1718 Var** | **1509 Var** | **Basmati** |
| 1 | Organic Carbon | Walkley Black method | 16.8±0.535 | 19.2±0.124 | 18.4±0.193 | 23.1±0.368 |
| 2 | Nitrogen | Kjeldahl's method | 0.47±0.0205 | 0.56±0.024 | 0.49±0.028 | 0.5±0.0408 |
| 3 | Potassium | Flame photometry | 2.3±0.205 | 1.91±0.0124 | 1.21±0.021 | 2.29±0.081 |
| 4 | Phosphorus | Atomic Absorption Spectroscopy | 0.21±0.0205 | 0.23±0.016 | 0.2±0.026 | 0.24±0.044 |

### 6.3Table-Burning Behaviour of stubble

Basmati has good amount of all the nutrients. Nitrogen content is highest in 1718 variety.

*6.3.1 Based on Buring behaviour-*

Particulate matter and Nitrogen dioxide released by 1718 variety is the highest. Sulphur dioxide, Carbon Monoxide and Hydrocarbon is released in good amounts by 1121 var. while Carbon dioxide is released in maximum amount by 1509 variety.

## GRAPHICAL REPRESENTATION

### 7.1 Physical Characteristic Graphs -

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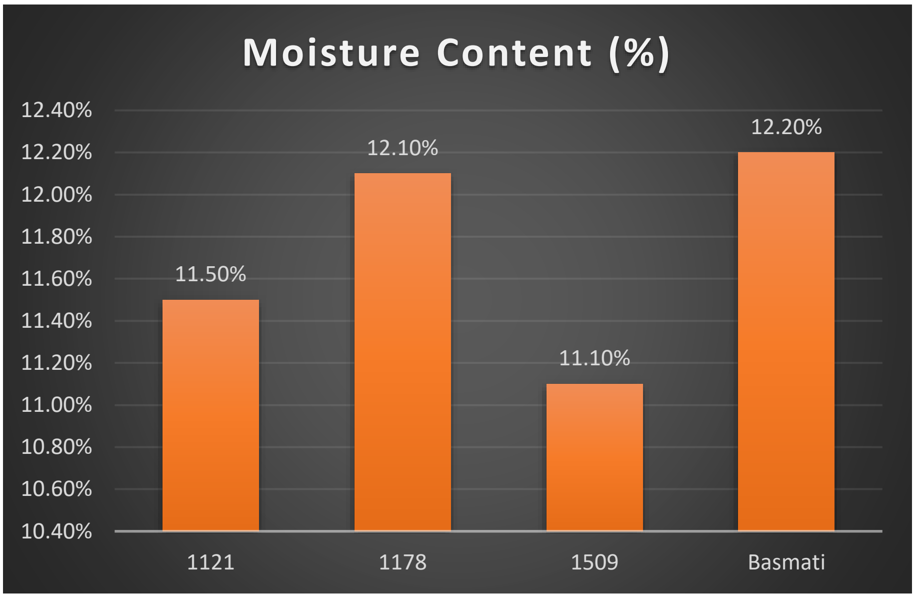
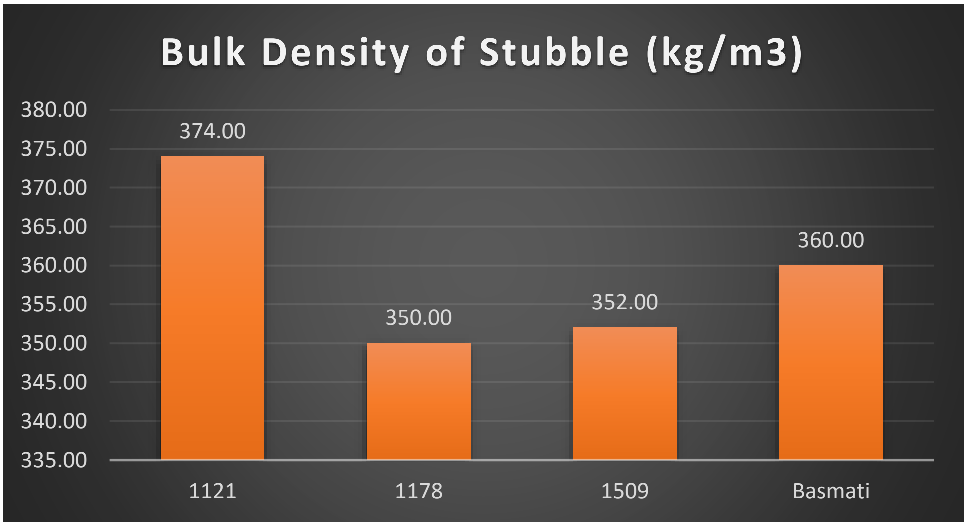
*7.1.1 Moisture Content*

| S. No. | Parameter | 1121Var | 1718Var | 1509Var | Basmati | Method |
|---|---|---|---|---|---|---|
| 1 | Particulate Matter(mg/Nm3) | 139±1.699 | 153±2.16 | 148±2.49 | 139±1.800 | Flue Gas Analyzer |
| 2 | Sulphur Dioxide(ppm) | 28.4±0.535 | 24±0.294 | 23.8±0.748 | 17±1.111 | Flue Gas Analyzer |
| 3 | Nitrogen dioxide(ppm) | 298.7±0.880 | 715±1.545 | 410±1.433 | 443±2.94 | Flue Gas Analyzer |
| 4 | Carbon dioxide(ppm) | 1076±2.49 | 1064±0.956 | 1085±2.054 | 1025±1.062 | Flue Gas Analyzer |
| 5 | Carbon monoxide(ppm) | 127±1.506 | 125±1.801 | 125±1.35 | 100±1.228 | Flue Gas Analyzer |
| 6 | Hydrocarbon(ppm) | 1800±1.177 | 1484±2.69 | 1740±2.77 | 1700±2.88 | Flue Gas Analyzer |




*7.1.2 Bulk Density of Stubble*




*7.1.3 Porosity of Stubble*

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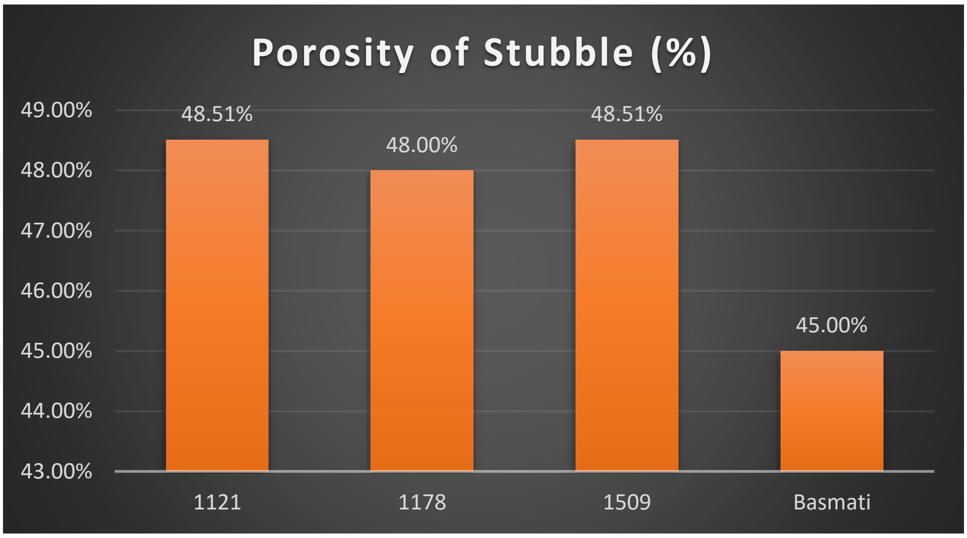
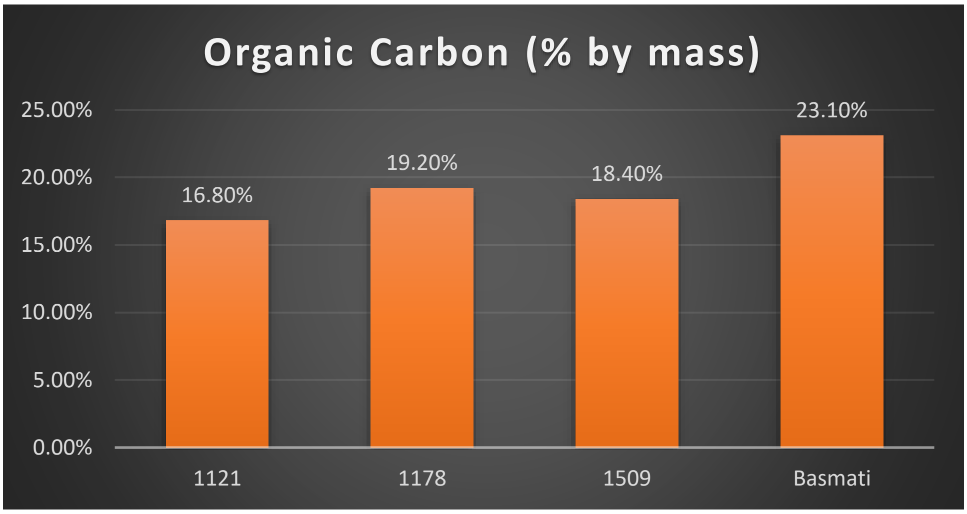



**7.2. Chemical Analysis Graphs -**

*7.2.1 Organic Carbon*




*7.2.2 Nitrogen*

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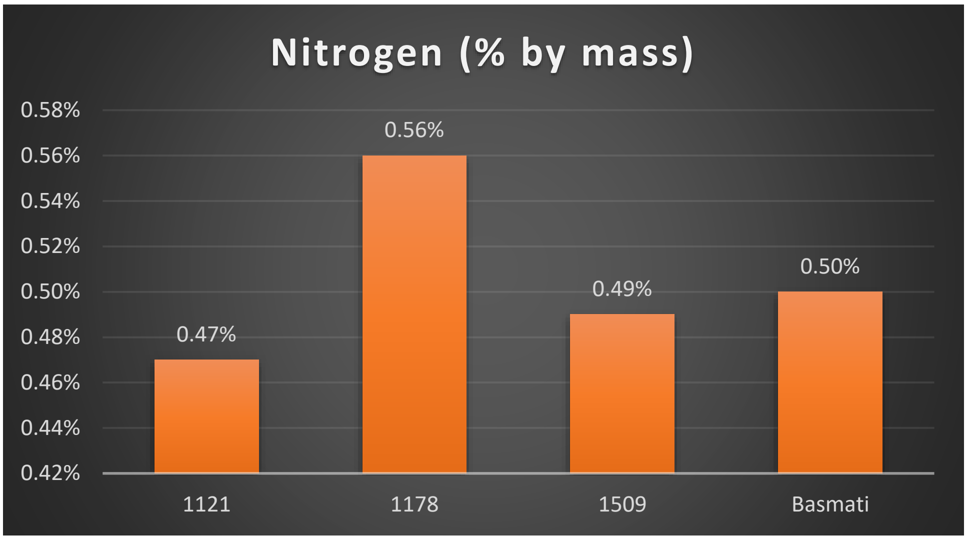
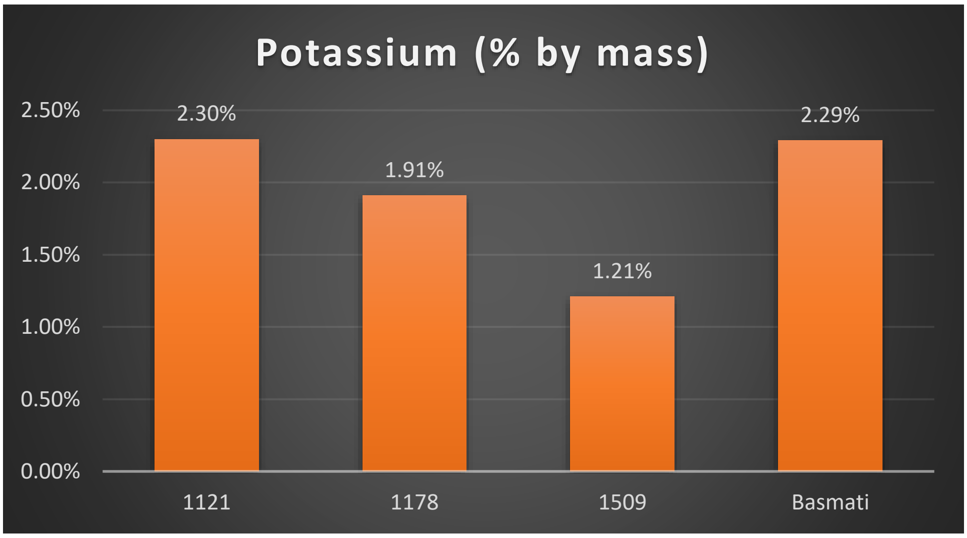



*7.2.3 Potassium*




*7.2.4 Phosphorus*

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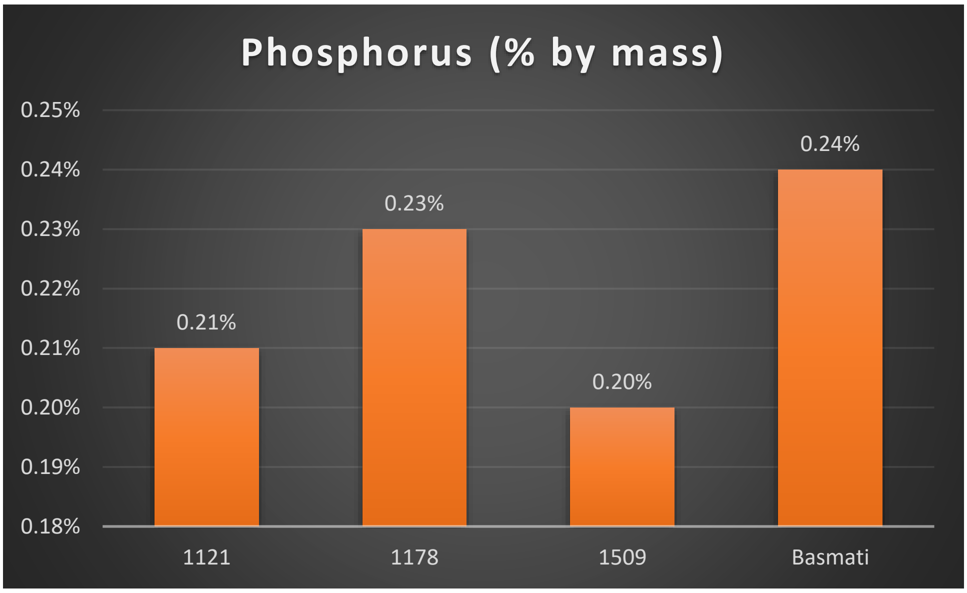
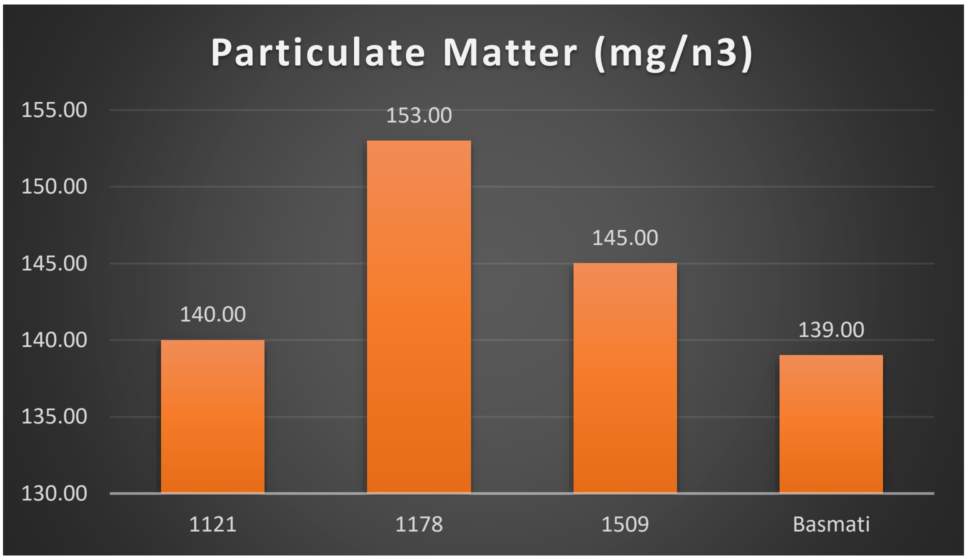



### 7.3 Burning Behaviour

*7.3.1 Particulate Matter*




*7.3.2 Sulphur Dioxide*

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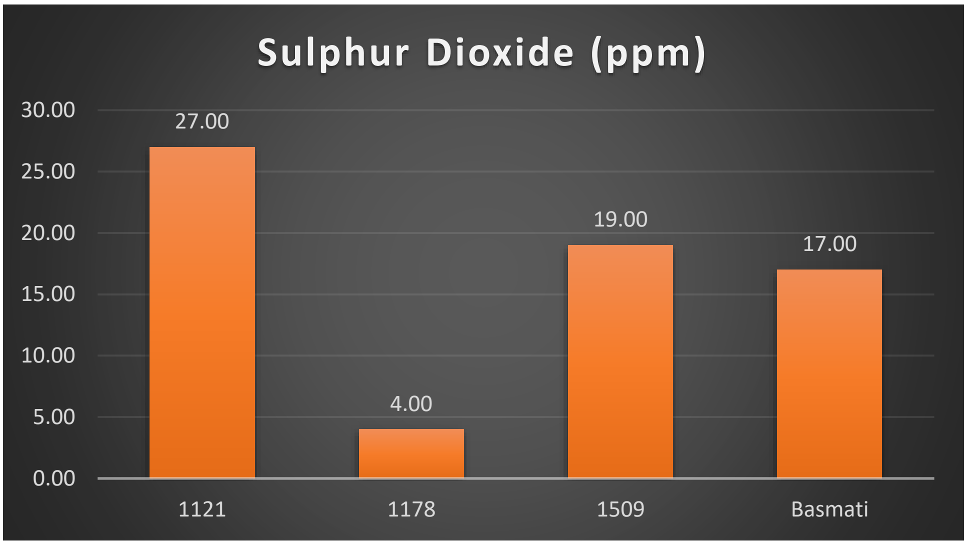
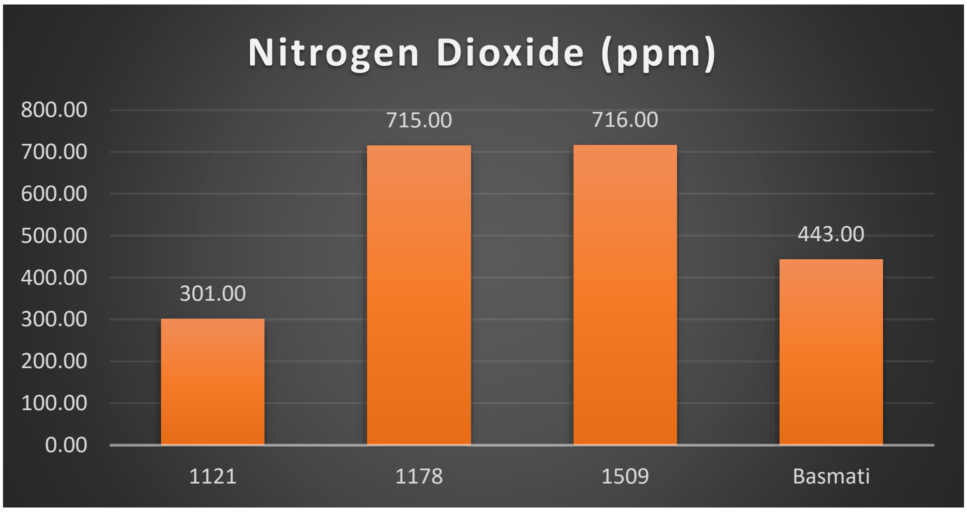
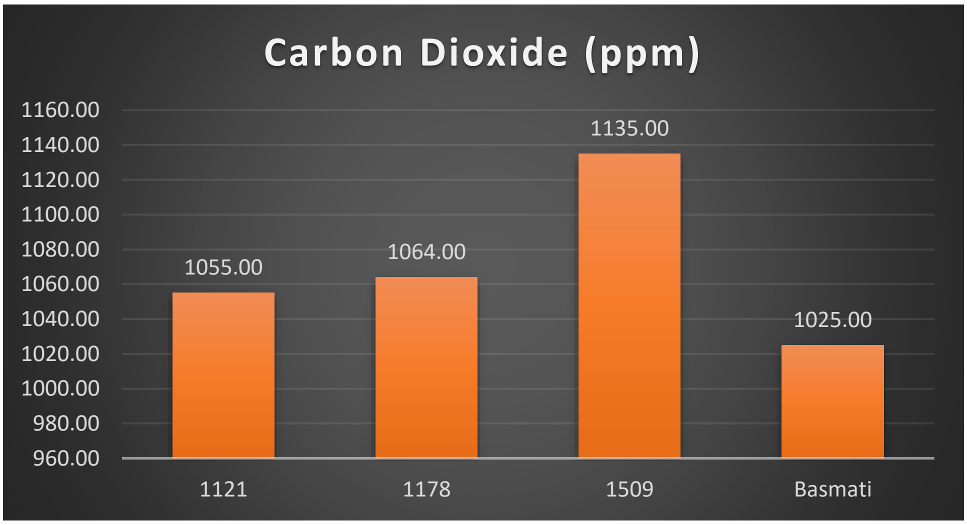



*7.3.3 Nitrogen Dioxide*




*7.3.4 Carbon Dioxide*




*7.3.5 Carbon Monoxide*

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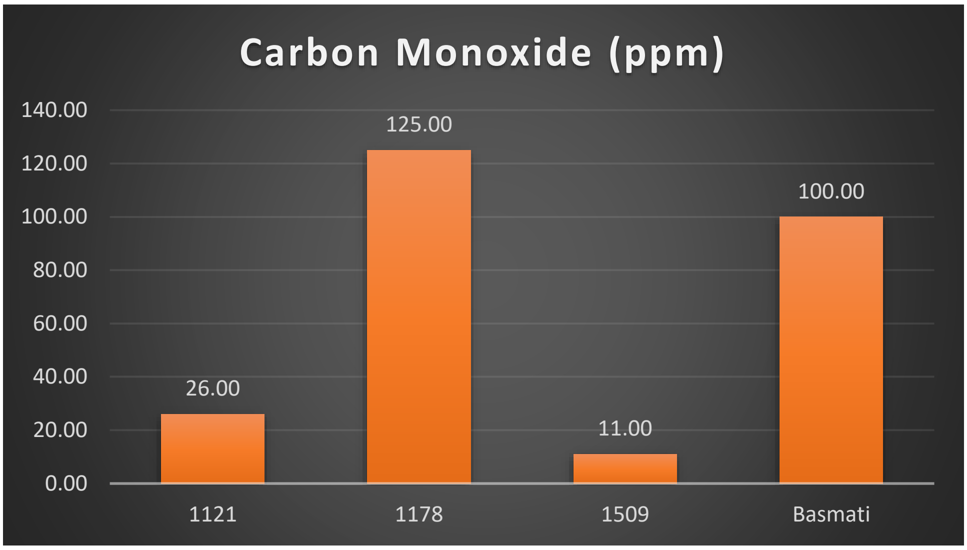
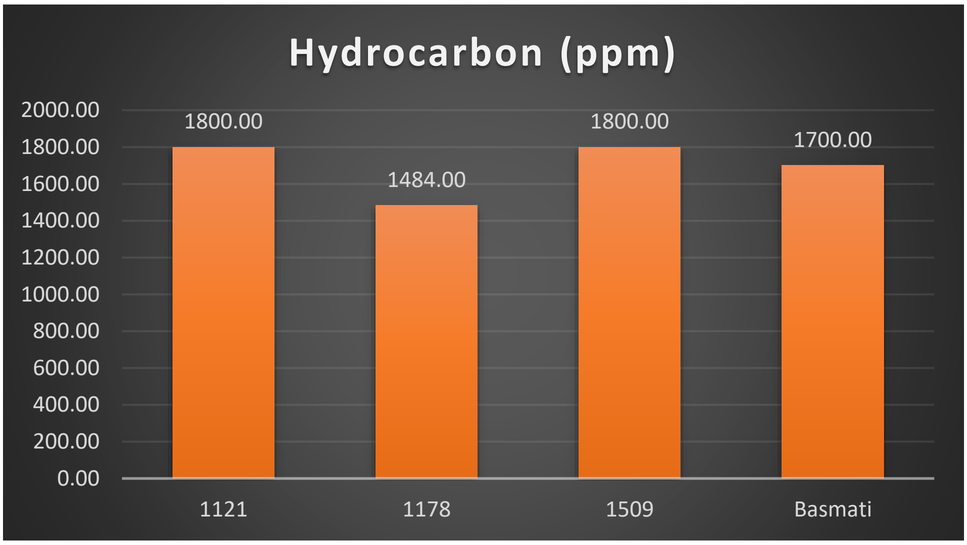



*7.3.6. Hydrocarbon*




**8.1 Secondary Data from CPCB site**

8.1.1 Central Pollution Control Board Data and Graph indicating Air Quality in Delhi NCR from 30-10-2023 to 09-12-2023

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**CPCB data indicates that pollution is maximum around the first week of November which indicates that the pollutants are released when stubble is burnt.**

**Table 9.1** Statistical Analysis of Pollutants released

| Statistical Measures | *Particulate Matter (mg/n3)* | *Sulphur Dioxide (ppm)* | *Nitrogen Dioxide (ppm)* | *Carbon Dioxide (ppm)* | *Carbon Monoxide (ppm)* | *Hydrocarbon (ppm)* |
|---|---|---|---|---|---|---|
| Mean | 144.75 | 23.3 | 466.675 | 1062.5 | 119.25 | 1681 |
| Standard Error | 3.47 | 2.35 | 88.34 | 13.22 | 25.48 | 68.80 |
| Median | 143.5 | 23.9 | 426.5 | 1070 | 63.5 | 1720 |
| Standard Deviation | 6.946222 | 4.706 | 176.68 | 26.43861 | 50.97957 | 137.613 |
| Sample Variance | 48.25 | 22.147 | 31217.8 | 699 | 2598.917 | 18937.33 |
| Kurtosis | -3.57712 | 1.8057 | 2.26 | 1.966255 | -4.8268 | 2.47 |
| Skewness | 0.428906 | -0.7479 | 1.25 | -1.40255 | 0.202717 | -1.47 |
| Range | 14 | 11.4 | 416.3 | 60 | 100 | 316 |
| Minimum | 139 | 17 | 298.7 | 1025 | 25 | 1484 |
| Maximum | 153 | 28.4 | 715 | 1085 | 125 | 1800 |

**9.2Analysis of Data-**

*9.2.1. For Pollutants released-*

1.Particualte matter is released least by 1121 variety of Paddy
2.Basmati releases least amount of Sulfur Dioxide, Carbon monoxide, Carbon dioxide
3.Nitrogen dioxide is released in least amount by 1121 variety
4.Hydrocarbon is released in least amount by 1718 variety

*9.2.2For Physical properties-*

1.The physical properties of all three varieties is comparable while porosity of Basmati variety is the least while bulk density is least of 1159 and moisture content is least of 1178.

*9.2.3 Conclusion*

Hence it shows that varietal development is not supportive of burning of stubble as the traditional variety of Basmati is better than others in releasing less pollutants.

## RESULT DISCUSSION

The potential uses of paddy stubble, such as composting, bioenergy production, or nutrient recycling in agriculture can be known and to ensure safe and sustainable disposal practices when needed, performing a thorough physico-chemical characterization of the stubble is necessary.

Based on physical characteristics we can conclude that all of four varieties have relatively comparable characteristics.

Based on chemical characterization we can conclude that the nutrient content varies in each variety. Organic carbon content is highest in Basmati rice, while nitrogen content is highest in Pusa 1718, Pusa 1121 has highest level of potassium and Basmati has highest level of Phosphorus content.

Hence burning of stubble is not preferable by any means as it will result in the loss of nutrients present in the stubble. The physical characteristic of the stubble is useful to put the stubble to some other use like utilization for removal of heavy metals, biochar production, making bricks etc.

The burning behaviour of the stubble indicates that burning of the stubble of each variety of paddy is harmful as hazardous gases like carbon dioxide, carbon monoxide, nitrogen dioxide, sulphur dioxide along with particulate matter are being released by burning of stubble.

### Future Scope of Work

The stubble burning is a very popular act among the farmers of Haryana as it only needs to burn a matchstick for putting up the fire. But it has such bad implications which can be only stopped if the the farmer gets a value to the stubble by recylcing it to make a new product. This can only help in reducing the climatic change effect and health effects. Hence more detailed work must be done in this area.

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