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Assessment of Air Pollution as Influenced by *in situ* Sugarcane Trash Burning

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ABSTRACT

Sugarcane being C_4 grass is capable of producing large quantities of biomass. Out of total biomass about 75 per cent is cane stalk used for crushing in sugar industry and remaining 25 per cent left out of which nearly 12 to 15 per cent cane tops are fed to animals and remaining approximately 10 to 13 per cent left over sugarcane trash usually burnt by farmers due to lacking of complete awareness of proper sugarcane trash management techniques. An investigation was undertaken to assess the quality of ambient air (GHG's emission) as influenced by *in situ* sugarcane trash burning at village Padegaon, Dist. Satara, Maharashtra, India at 15 selected sites of recently harvested sugarcane plots (var. CoM 0265). The ambient air quality before and during *in situ* sugarcane trash burning was monitored. The greenhouse gas emission (ambient air quality) *viz.,* PM2.5µ, PM10µ, CO_2, NO_2, SO_2, CO, CH_4 and total VOC's concentrations were significantly increased to 59.94 µg M^{-3}, 268.53 µg M^{-3}, 545.27 ppm, 47.03 µg M^{-3}, 26.37 µg M^{-3}, 5.45 ppm, CH_4, 0.5 ppm, total VOC's 1.09 ppm, respectively with reduction in ambient O_2 level (19.35 %) due to trash burning. Further, the *in situ* sugarcane trash burning significantly increased greenhouse gas emission of PM2.5µ by 3.5 times, PM10µ, by 4 times CO_2 by 2 times, NO_2 by 6 times, SO_2 by 1.5 times, CO by 1.5 times, CH_4 by 2.5 times and total VOC's by 2 times with reduction in air O_2 by 1.5 times over baseline ambient air quality. The effect of *in situ* sugarcane trash burning on periodical temperature of flame at soil surface indicated that the highest mean temperature was raised to 797.7 ^oC immediately after 1.15 minutes from start of *in situ* burning. The temperature of flame remained about 106.89 ^oC up to 5.30 minutes. The *in situ* burning of sugarcane trash required maximum about 13.30 minutes period for complete burning of *in situ* sugarcane trash. The significant losses of nutrients present in sugarcane trash, the significant increase in air pollution of greenhouse gases *viz.,* PM2.5µ, PM10µ, CO_2, NO_2, SO_2, CO, CH_4 and total VOC's with reduction in O_2 level in ambient air was observed due to *in situ* sugarcane trash burning.

Keywords: Sugarcane, *in situ* sugarcane trash burning, air pollution.

INTRODUCTION

India is contributing about 21.4 per cent area and 23 per cent production globally and ranks second among sugarcane growing countries of the world next to Brazil. Maharashtra is a leading state, stood first in cane production and sugar recovery with the highest number of co-operative and private sugar factories network (Annonymous, 2023). Currently, sugarcane growers are facing problems such as decline in productivity, soil health deterioration, improper management of farm crop residues, increasing cost of production particularly due to increasing cost of inputs *viz.* organic manures, chemical fertilizers, labour charges, intercultivation etc. and fluctuating sugarcane prices. Sugarcane after harvest leaves behind 8 to 13 t ha^{-1} of sugarcane trash, 4 to 5 t ha^{-1} of stubbles and adequate amount

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of root mass (Phalke et al. 2014, 2015). Sugarcane is a C_4 photosynthetic gigantic perennial grass, which utilizes maximum solar radiations. Sugarcane has most efficient photosynthetic mechanisms amongst the commercial cash crops and these photosynthetic capabilities allow CO_2 fixation for minimizing GHG's emission (Gangwar et al. 2022).

Sugarcane being a C_4 grass is capable of producing large quantities of biomass. Out of total biomass, about 75- 80 per cent is cane stalk which is source to sugar, power, alcohol and other allied products. The remaining biomass (about 25 per cent) is left out in the field after green cane harvest. The biomass comprising tops, dried and green leaves is called as trash. The plant nutrients contained in cane trash are lost because of trash burning. Trash is usually burnt results in potential loss of useful organic matter and plant nutrients. In Maharashtra alone, more than 105 lakh tons of sugarcane trash is produced and excluding some portion for conventional use, rest of the part of sugarcane trash burnt every year. As the compost making from sugarcane trash has not become yet popular, because it decomposes at a very slow rate due to wider C:N ratio and it is not economically viable as it requires land, labors and time for handling. Burning kills the upper buds of the stubble and allows sprouting the deeper ones. After harvest of sugarcane, farmers used to burn trash, sometimes it is utilized by people for covering huts and house roofs for shelter in rural areas and recently it is utilized as a fuel for jaggery and other allied industries situated in adjoining sugarcane areas and for cogeneration in power plants (Natrajan, 2009).

Currently the cane trash in most of the developing countries where green cane harvesting is prescribed as burnt, polluting the atmosphere. Under the present conditions, trash, a residue of cane from the field is considered as liability. Burning cane trash emits GHG's and other causative chemical substances and pollutes the atmosphere. On an average burning of one tonne of sugarcane trash emits 35.3, 2.7 and 2.3 kg of carbon monoxide, particulate matter and volatile organic compounds (VOC's), respectively, which is responsible for global warming (Perumal, 2002). Sugarcane by virtue of its inherent biomass capacity as a C4 plant consumes more CO_2 there by reduces CO_2 load from atmosphere. It fixes 159.9 t of CO_2 $ha^{-1}yr^{-1}$ and one ton of biomass of sugarcane fixes 1.46 billion t of CO_2 and releases 1.09 t of O_2 annually (Anders, 1988). However, manmade practices like burning of pre and post harvest cane trash emits NO_2, CO_2 and other causative chemical substances favoring global warming, ozone layer depletion and acidification of the environment. Hence, the practice of trash burning is an international issue for global warming and also cane burning and trash burning plays an overriding role in contributing to the health problems.

Sugarcane trash is an important component of environmental pollution and associated with health effects, the production of substantial quantities of CO_2 and GHG can adversely affect the environment. The sugarcane trash can be converted to high value manure of quality better than FYM. Its use along with chemical fertilizers not only sustains present level of crop yields but also increase it. The recycling of crop residues is essential for supplementing plant nutrients and returning at least a part of the nutrients drawn from the mother earth. In sugarcane *in situ* recycling of sugarcane trash in relation to soil fertility can be carried out in different ways such as *in situ* mulching in ratoon and plant cane and *in situ* incorporation after harvest of ratoon cane. It would however require policy interventions perhaps both at the level of the state and central governments.

With the above facts and views, it is felt need not only to the farmers but for a government policy issue that it urgently needs to develop awareness among farming community about ill effects of trash burning and for adoption of *in situ* recycling technology of sugarcane trash for maintenance of soil health, recycling of valuable nutrients and to ascertain SOC sequestration by controlling GHG emission from sugarcane fields. At present, knowledge of emission from burning of sugarcane crop residues and its impact on soil properties is very limited. Therefore, there is need of information on effects of trash burning on soil health and requirement of monitoring of emission from sugarcane crop residue burning to quantify the pollutants released in the environment. These pollutants can be transported over long distances and result in low radiation due to aerosol formation, elevated oxidant levels, acid deposition and decreased sugarcane productivity. An

investigation was undertaken to assess the quality of ambient air (GHG's emission) as influenced by *in situ* sugarcane trash burning.

MATERIALS AND METHOD

The experimental field survey was conducted during December, 2021 to February, 2022 in village Padegoan, Tal. Phaltan, Dist. Satara, Maharashtra in the periphery of Meteorological observatory of the Central Sugarcane Research Station, Padegaon, Dist. Satara (Maharashtra). Geographically, it is located at 180012' (N) latitude and 74014' (E) longitude and at an elevation of 556 m above MSL. The total 30 representative air samples were collected from selected sites during the period of 23 to 25 February, 2022. The air samples were collected for monitoring of ambient air quality before and during *in situ* burning by using Respirable Dust Sampler (RDS) and Fine Dust Sampler (FDS) as per standard methods and simultaneously analyzed in laboratory of Division of Environmental Science, MITCON Consultancy and Engineering Services Ltd., Pune.

A newly harvested 15 sugarcane plots (var. CoM 0265) in the periphery of Meteorological observatory of the Central Sugarcane Research Station, Padegaon, were selected for conduct of field experiment during winter season of year 2022. The latitude and longitude of the selected locations were recorded. The meteorological data *viz.*, wind speed, air temperature, relative humidity, rainfall, etc. was collected during course of investigation. The sugarcane trash from 4000 m^2 area was collected, quantified and utilized for *in situ* burning. The baseline ambient air quality *viz.*, CO, particulate matter (2.5 µ and 10 µ), SOx, NOx, VOC's and O_2 etc. prior to *in situ* trash burning was monitored by Respirable Dust Sampler (RDS) and Fine Dust Sampler (FDS) at all 15 selected locations for the period of six hours as per the guidelines of Central Pollution Control Board (CPCB). The ambient air quality during course of trash burning at all 15 locations were monitored by Respirable Dust Sampler (RDS) and Fine Dust Sampler (FDS) for the period of six hours by considering wind direction as per standard method. The periodical temperature of flame at soil surface was recorded during the course of *in situ* trash burning by pyrometer at an interval of 0.15 minutes up to complete burning of trash. The collected air samples were analyzed in laboratory.

The CO_2 concentration from gas samples was determined by gas chromatography (Lodge, 1988). The electrochemical carbon dioxide sensors measures electrical current to determine how much CO_2 present in the air. When CO_2 enters the sensor, it chemically reacts within a polymer surface, resulting in an electrical charge. The type and amount of electrical charge is then used to determine how much CO_2 is present. Reported the carbon dioxide concentration in per cent.

The NO_2 concentration from gas samples was determined by Sodium arsenite method (IS, 2006a).The gaseous samplers were used. In impinger sodium hydroxide and sodium arsenite solution is used as absorbing medium for NO_2, the sampling was done for 24 hrs. Then in collected sample 1 ml hydrogen peroxide was added followed by 10 ml of sulphanilamide solution and 1.5 ml NEDA added and make up the final volume to 50 ml. The absorbance was recorded at 540 nm wavelength. Linearity curve of working NO_2 is from 1 to 15 mg L^{-1}. The factor is calculated from linearity curve. Calculation was done by following formula for NO_2

$$NO_2\ (\mu gM^{-3}) = \frac{NO_2 \text{ conc by graph x dilution factor x final volume of sampling solution in ml}}{\text{Vol of air sampled x aliquot taken for analysis x 0.82}}$$

The SO_2 concentration from gas samples was determined by spectrophotometery method (IS, 2001).Gaseous samplers were used. In impinger 0.04 M TCM absorbing solution was used as absorbing medium for SO_2. sampling is done for 24 hrs then collected sample added 1 ml of 0.6 per cent sulphamic acid then 2 ml of 0.2 per cent formaldehyde and 5 ml of para rosaniline and absorbance is recorded at 560 nm wavelength. Linearity curve of working sulphite standard is from 0.5 to 5 mgL^{-1}. The factor was calculated from linearity curve calculation was done by following formula for SO_2

$$SO_2 \ (\mu gM^{-3}) = \frac{\text{(sample absorbance - blank absorbance) x 1000 x calibration factor}}{\text{Volume of air passed}}$$

The CO concentration from gas samples was determined by gas chromatography method (IS, 1999). The apparatus consists of a chromic acid scrubber, a drying tube containing phosphorus pentoxide and potassium hydroxide, a U-tube packed with iodine pentoxide maintained at correct temperature (145^0C) and bubbler to absorb either carbon dioxide in baryta or iodine in potassium iodide solution or a known volume of standard thiosulphate solution. A blank determination was done before analysis was to be performed. Fresh 10 per cent potassium iodide solution was taken in the trap. Nitrogen was passed through stopcock for 30 minutes, the solution in the potassium iodide trap titrated with standard sodium thiosulphate solution. The amount of free iodine thus obtained was considered the blank of the apparatus and should be subtracted from subsequent determinations.

The apparatus was again purged with nitrogen for about 30 minutes. Stopcocks were closed. The potassium iodide trap was disconnected and its contents titrated for free iodine. X Volume of thiosulphate in ml X normality of thiosulphate (where the volume of sodium thiosulphate used in ml was the volume to titrate the iodine liberated in the analysis of the sample).

$$\text{Carbon monoxide } (\mu g\ M^{-3}) = \frac{0.07 \text{ x Volume of thiosulphate x Normality of thiosulphate x } 109}{\text{Volume of gas sample (L)}}$$

The CH_4 concentration from gas sample was determined by gas chromatography method (Lodge, 1988a) Quantitative analysis of methane content by GC with FID as detector, the peak area is proportional to the methane volume injected into GC system. Based on the quantitative relationship, various volumes of standard gas injected into the GC system were equivalent to corresponding methane content in the volume of 500 µL, which was the injection volume in this method. The equivalent contents (EC) of methane gas converted from standard gas with diverse injection volumes (IV, µL) were calculated according to the equation (1), which was shown as below.

$$EC = \frac{IV \text{ X } 44\%}{500\ \mu L}$$

The total VOC's from gas sample was determined by gas chromatography method (Lodge, 1988) VOC sensor module works on the principle of PID technology for the measurement of VOC gases. It uses high-energy photons to detect VOC levels. The air sample drawn into the TVOC sensor was exposed to UV light of a specific output that excites the VOC molecules present in the air sample. Reported as mg L^{-1}

$$\text{Cs (Concentration of benzopyrene in } \mu g\ ml^{-1}) \quad \frac{As \text{ x } Cis}{Ais \text{ xX } RF}$$

Where as

As = area count of characteristic analyte

Ais = area count of characteristic internal

Cis = concentration of internal standard

Rf = Response factor

The Particulate Matter 2.5µ (PM2.5µ) concentration from gas sample was determined by gravimetric method (EPA, 2016). For PM2.5µ and PM10µ the fine particular samplers and respirable dust samplers were used. PTFE membrane filter paper of 47 mm diameter is used for PM2.5µ sampling in which initial weight of filter paper was taken. Initial and final flow is considered. The sampling was done for 24 hrs after that final weight of the PM2.5µ paper was taken and calculation is done by following formula for PM2.5µ

$$\text{PM 2.5}\mu\ (\mu g\ M^{-3}) = \frac{\text{(final wt of filter paper - initial wt of filter paper) x } 106}{\text{Volume of air passed}}$$

The Particulate Matter 10µ (PM10µ) concentration from gas sample was determined by gravimetric method (IS, 2006b) For PM10µ respirable dust samplers and EPM 2000 filter paper is used initial weight of the filter paper was taken. Initial and final flow was considered sampling is done for 24 hrs after that final weight of PM10µ paper was taken and calculation was done by following formula for PMµ

$$PM\mu\ (\mu g\ M^{-3}) = \frac{\text{(final wt of filter paper - initial wt of filter paper) x 106}}{\text{Volume of air passed}}$$

The Oxygen (O_2) concentration from gas sample was determined by gas chromatography method (Lodge, 1988b). The basic principle is that there was a cathode and an anode submersed in an electrolyte. Oxygen enters the sensor through a permeable membrane by diffusion and is reduced at the cathode, creating a measurable electric current. There was a linear relationship between the oxygen concentration and the electric current.

Bomb Calorimeter was standardized by igniting a pellet of Benzoic Acid of known calorific value weighing one gram or less in oxygen sealed bomb. By igniting benzoic acid, water equivalent (W) was evaluated which is the weight of water equivalent in effective heat capacity to the entire system (Calorimeter vessel containing a specified weight of water, bomb charged with oxygen, combustion aid and fuel). You need to know this value in order to determine how much heat is generated by combustion of the sample.

The water equivalent of the system is determined by igniting a pellet of supplied pure and dry benzoic acid of known calorific value weighing not less than 0.8 and not more than 1.0 gram. Record the corrected temperature rise (T), calculate the calorific values of thread and wire (CVT and CVW) using the data given below and evaluate water equivalent by substitution in the equation.

$$\text{Water Equivalent (W)} = \frac{H \times M + (CVT + CVW)}{T}$$

Where: T = Final rise in Temperature in Degree Celsius

M = Mass of sample in grams

H = Known Calorific Value of Benzoic Acid in cal/gram

W = Water Equivalent in calories per degrees centigrade

CVT = Calorific Value of thread

CVW = Calorific Value of Ignition wire

CVs = Calorific Value of Sample in calories per gram

$$\text{Calorific value (CVs) in cal } g^{-1} \quad \frac{TxW - (CVT + CVW)}{M}$$

RESULTS AND DISCUSSION

The present investigation was undertaken from December, 2021 to February, 2022 on 15 locations of farmers fields at village Padegaon, Tal. Phaltan, Dist. Satara, Maharashtra to characterize sugarcane trash and it's a ash after *in situ* burning, assessment of air pollution as influenced by *in situ* sugarcane trash burning.

Biomass of sugarcane trash and sugarcane trash ash

The location wise biomass of *sugarcane trash* before *in situ* burning and *sugarcane trash ash* generated

after *in situ* burning were quantified and presented in (Table 1). The weight of *sugarcane trash* was ranged from 12.5 t ha^{-1} to 14.9 t ha^{-1} with mean value 13.61 t ha^{-1}. The weight of sugarcane trash ash was observed between 0.91 t ha^{-1} to 1.41 t ha^{-1} with mean value 1.13 t ha^{-1}. The per cent range of trash ash was observed to the tune of 7.28 to 9.46 per cent of weight of sugarcane trash with an average 8.84 per cent. Many investigators have summarized the quantification of sugarcane trash and sugarcane trash ash. (Bhoi et al. 2004; Perumal 2002; Dixit et al. 2007; Verma et. al. 2004; Phalke et. al. 2015).

Table 1 : Location wise biomass of sugarcane trash and sugarcane trash ash

Location	Weight of sugarcane trash (t ha^{-1})	Weight of sugarcane trash ash (t ha^{-1})	Per cent ash (%)
L_1	13.4	1.04	7.76
L_2	13.7	1.17	8.54
L_3	13.1	1.10	8.40
L_4	12.8	1.16	9.06
L_5	14. 4	1.07	7.43
L_6	14.8	1.30	8.78
L_7	12.7	1.00	7.87
L_8	12.8	1.05	8.20
L_9	14.5	1.26	8.69
L_{10}	13.8	0.98	7.10
L_{11}	12.5	0.91	7.28
L_{12}	12.8	1.14	8.91
L_{13}	14.4	1.35	9.38
L_{14}	14.9	1.41	9.46
L_{15}	13.6	1.05	7.72
Mean	13.61	1.13	8.30
.SE (±)	0.21	0.04	-
Max	14 .90	1.41	9.46
Min	12.50	0.91	7.28
Range	2.40	0.50	-

Characterization of sugarcane trash and sugarcane trash ash

Sugarcane trash before *in situ* burning and its ash generated after *in situ* burning of sugarcane trash were collected and analyzed for nutrient content and presented in Table 2 and 3.

Sugarcane trash

The data showed the total organic carbon (TOC) was ranged between 39.69 per cent to 42.92 per cent with mean value 41.66 per cent. There was difference of 2.23 per cent between minimum and maximum TOC concentration in sugarcane trash. The total nitrogen content in sugarcane trash was registered from 0.42 per cent to 0.58 per cent with mean value 0.51 per cent. The total phosphorus was estimated between 0.28 to 0.38 per cent. The mean value was 0.34 per cent. In case of total K, it was found in the range of 0.81 per cent to 0.93 per cent with mean value of 0.87 per cent. The total sulphur was noticed from 0.15 per cent to 0.18 per cent with mean value 0.16 per cent. There was wide variation in iron content in sugarcane trash. The minimum value of total Fe was noted 2.01 mg kg^{-1} and maximum value was noted 19.59 mg kg^{-1} with mean value of total Fe 8.68 mg kg^{-1}. The values of total manganese were observed within 1.18 mg kg^{-1} to 1.73 mg kg^{-1} and mean value was 1.47 mg kg^{-1}. The values of total zinc were ranged between 0.89 to 1.64 mg kg^{-1} with mean value 1.32 mg kg^{-1}. The

Table 2 : Location wise chemical composition of sugarcane trash

Sugarcane trash	Parameters								
	TOC (%)	Total N (%)	Total P (%)	Total K (%)	Total S (%)	Total Fe (mg kg^{-1})	Total Mn (mg kg^{-1})	Total Zn (mg kg^{-1})	Total Cu (mg kg^{-1})
L_1	42.15	0.56	0.28	0.86	0.17	7.76	1.57	1.5	0.59
L_2	41.37	0.56	0.29	0.85	0.17	8.66	1.68	1.34	0.32
L_3	41.7	0.56	0.3	0.93	0.17	17.41	1.6	1.64	0.51
L_4	41.69	0.58	0.32	0.84	0.17	7.04	1.49	1.32	0.36
L_5	42.87	0.56	0.32	0.83	0.16	8.87	1.18	1.34	0.53
L_6	39.94	0.42	0.32	0.83	0.16	19.59	1.73	1.39	0.34
L_7	41.08	0.56	0.34	0.89	0.15	15.01	1.26	1.6	0.38
L_8	39.69	0.53	0.35	0.83	0.15	7.31	1.27	1.25	0.69
L_9	41.17	0.56	0.35	0.83	0.16	7.15	1.34	1.22	0.33
L_{10}	42.9	0.42	0.35	0.86	0.18	6.05	1.56	1.12	0.3
L_{11}	42.7	0.42	0.36	0.86	0.16	8.93	1.29	1.1	0.28
L_{12}	40.02	0.48	0.38	0.81	0.16	5.41	1.53	1.03	0.23
L_{13}	42.92	0.53	0.36	0.85	0.16	2.01	1.45	0.89	0.28
L_{14}	42.57	0.42	0.34	0.86	0.16	5.02	1.52	1.51	0.26
L_{15}	42.15	0.56	0.38	0.87	0.17	3.91	1.51	1.48	0.29
Mean	41.66	0.51	0.34	0.85	0.16	8.68	1.47	1.32	0.38
SE (±)	0.29	0.02	0.01	0.01	0.00	1.28	0.04	0.06	0.04
Max	42.92	0.58	0.38	0.93	0.18	19.59	1.73	1.64	0.69
Min	39.69	0.42	0.28	0.81	0.15	2.01	1.18	0.89	0.23
Range	3.23	0.16	0.10	0.12	0.03	17.58	0.55	0.75	0.46

total copper content was registered between 0.23 mg kg^{-1} to 0.69 mg kg^{-1} in sugarcane trash with average value 0.38 mg kg^{-1}.

The numerical difference in total chemical composition of sugarcane trash might be due to cultivation of sugarcane plots under different locations having different soil chemical properties. It was noticed that the sugarcane trash contains major and micronutrients in better amount. It can be used as soil amendment for returning to soil which may minimize reliance on chemical fertilizers and also reducing environmental pollution caused by burning. These observations were also supported by Perumal 2002; Verma 2004; Sundra 2007; Meena et al. 2015; Phalke et al. 2015.

Sugarcane trash ash

The data on chemical composition of sugarcane trash ash are presented in Table 3. The data showed that, there was complete loss of organic carbon due to *in situ* burning of sugarcane trash. It can be revealed that there is 100 per cent loss of total organic carbon due to *in situ* burning of sugarcane trash. The content of total N in sugarcane trash ash was below detectable level. *In situ* burning of sugarcane trash resulted in significant reduction in total N which have gone up to non detectable level. As far as total P is concern, it ranged from 0.08 to 0.11 per cent. There was about 71 per cent loss in total phosphorus in sugarcane trash due to *in situ* burning. In respect of total potassium, the values ranged between 0.17 to 0.20 per cent. It could be seen from the data, the value of total K were depleted by about 79 per cent of the values of total K in sugarcane trash before burning. The value of total sulphuer in ash more over was observed to be 0.03 per cent. It indicated that there was about 80 per cent loss of sulphuer due to burning of sugarcane trash. The value of total Fe registered between 1.59 mg kg^{-1} to 15.48 mg kg^{-1}. The total Fe content was reduced to about 21 per cent. The values of total Mn were ranged from 1.11 to 1.63 mg kg^{-1} with reduction of 21 per cent due to *in situ* burning of sugarcane trash. There was demarkable reduction in total Zn in trash due to burning, as there was reduction in total Zn up to 94 per cent. The values of total Zn were registered between 0.06 to 0.11 mg kg^{-1}. The total Cu content was ranged from 0.20 to 0.61 mg kg^{-1} with reduction of 21 per cent as compared with Cu content in sugarcane trash.

The data further indicated that there was significant difference in all nutrients except TOC and total nitrogen studied at different locations. This might be due to variation in soil chemical properties and management of fertilizers at different locations resulted in significant difference in chemical composition of sugarcane trash ash. The initial soil fertility status might have governed nutrient uptake significantly at different locations. The similar type of reduction in nutrients due to burning of sugarcane trash was observed by Perumal (2002).

Table 3 : Location wise chemical composition of sugarcane trash ash

Sugarcane trash ash	Parameters								
	TOC (%)	Total N (%)	Total P (%)	Total K (%)	Total S (%)	Total Fe (mg kg^{-1})	Total Mn (mg kg^{-1})	Total Zn (mg kg^{-1})	Total Cu (mg kg^{-1})
L_1	0	ND	0.08	0.18	0.03	6.13	1.48	0.11	0.53
L_2	0	ND	0.09	0.18	0.03	6.84	1.58	0.09	0.28
L_3	0	ND	0.09	0.20	0.03	13.75	1.50	0.11	0.45
L_4	0	ND	0.10	0.18	0.03	5.56	1.40	0.09	0.32
L_5	0	ND	0.10	0.17	0.03	7.01	1.11	0.09	0.47
L_6	0	ND	0.10	0.17	0.03	15.48	1.63	0.10	0.30
L_7	0	ND	0.10	0.19	0.03	11.86	1.18	0.11	0.34
L_8	0	ND	0.11	0.17	0.03	5.77	1.19	0.09	0.61
L_9	0	ND	0.11	0.17	0.03	5.65	1.26	0.09	0.29
L_{10}	0	ND	0.11	0.18	0.04	4.78	1.47	0.08	0.27
L_{11}	0	ND	0.11	0.18	0.03	7.05	1.21	0.08	0.25
L_{12}	0	ND	0.11	0.17	0.03	4.27	1.44	0.07	0.20
L_{13}	0	ND	0.11	0.18	0.03	1.59	1.36	0.06	0.25
L_{14}	0	ND	0.10	0.18	0.03	3.97	1.43	0.11	0.23
L_{15}	0	ND	0.11	0.18	0.03	3.09	1.42	0.10	0.26
Mean	0	-	0.10	0.18	0.03	6.85	1.38	0.09	0.34
Max	0	-	0.11	0.20	0.04	15.48	1.63	0.11	0.61
Min	0	-	0.08	0.17	0.03	1.59	1.11	0.06	0.20
Range	0	-	0.03	0.03	0.01	13.89	0.52	0.05	0.41
Trash	41.66	0.51	0.34	0.85	0.16	8.68	1.47	1.32	0.38
Ash	0.00	-	0.10	0.18	0.03	6.85	1.38	0.09	0.34
SEm (±)	0.20	-	0.01	0.01	0.00	1.15	0.04	0.04	0.03
CD at 5%	0.59	-	0.02	0.02	0.00	NS	NS	0.11	NS

*ND-Not detected

Effect of in situ sugarcane trash burning on ambient air quality (Green house gas emission)

The ambient air quality (green house gas emission) *viz.,* CO_2, NO_2, SO_2, CO, CH_4, total VOC's, $PM_{2.5\mu}$, $PM_{10\mu}$ and O_2 as influenced by *in situ* burning of sugarcane trash were monitored from selected experimental sites from village Padegaon, Dist. Satara, Maharashtra and presented in (Table 4). The higher air pollution exposure leads to direct impact on human and biotic factors. The CPCB had initiated National Ambient Air Quality Monitoring Programme since from 1984. Under this programme air pollutants like So_x, NO_x, CO_2, VOC's and particulate matters are being monitored by CPCB at selected locations (Annonymus, 2020).

Particulate matter (PM2.5µ)

The *in situ* burning of sugarcane trash emits particulate matter *viz.,* PM2.5µ, PM10µ, CO_2, NO_2, SO_2, CO, CH_4 and various VOC's during the course of investigation, it was found that before burning of the sugarcane trash PM2.5µ was observed in range of 15.25 to 18.00 µg M^{-3}. The drastic change in PM2.5µ concentration was reported during burning of the sugarcane trash ranging from 55.80 to 64.10 µg M^{-3}. However, the significant change was observed in the range of PM2.5µ was reported from 2.7 to 8.3 µg M^{-3}. The PM2.5µ is major contributor in GHG's emission. This PM2.5µ is the air pollutant directly affecting human health and agricultural productivity. This is physical parameter and cannot be controlled by mitigation strategies. It was reported that the plant photosynthesis exposed to fine particulate matter PM2.5µ drastically reduces rate of photosynthesis (Li et al. 2019). The average levels of PM2.5µ was reported 16.66 µg M^{-3} before burning of sugarcane trash, however it was directly increased to tune of 3.5 times (59.94 µg M^{-3}) due to *in situ* sugarcane trash burning. Similar findings are also reported by Lara et al. 2005; Venkatraman et. al. 2006; Jain et al. 2014 and Irfan et al. 2014.

Particulate matter (PM10µ)

During burning the ambient PM10µ levels were ranging from 90.2 to 107.6 µg M^{-3}. At all the sampling locations during burning period of the sugarcane trash significantly higher concentrations of PM10µ were recorded. The minimum value of 242 µg M^{-3} and maximum value of 289 µg M^{-3} was reported during *in situ* sugarcane trash burning. This study clearly showed that the concentration of PM10µ was drastically increased to the tune of 3 times (268 µg M^{-3}) to the base line PM10µ value of 99.60 µg M^{-3} due to *in situ* sugarcane trash burning. The range before burning and after burning of sugarcane trash for PM10µ was 17.4 and 47.00 µg M^{-3}, respectively. Burning of organic wastes majorly contributes particulate organic matter in the form of PM10µ. Similar finding were also reported by (Lara et al. 2005; Jimeneza et al. 2006; Venkatraman et al. 2006; Jain et al. 2014 and Irfan et al. 2014).

Carbon Dioxide (CO_2)

Burning of organic matter leads to generate CO_2 by reducing oxygen levels. It was found that the concentration of CO_2 in the ambient air before *in situ* trash burning was ranging from 289 to 327 ppm. During burning of sugarcane trash the CO_2 levels were reported ranging from 512 to 580 ppm. The range of CO_2 concentration before burning of sugarcane trash was 38 ppm. It was observed that the concentration of CO_2 was increased by 1.5 times (545 ppm) to the base line CO_2 value of 308 ppm due to *in situ* burning of sugarcane trash. However, the concentration of CO_2 was significantly increased (68 ppm) during *in situ* burning scenario of sugarcane trash. The CO_2 concentrations in the ambient air quality reported to be increased from mean value of 308 to 545 ppm due to burning of sugarcane trash. The significant quantity of air pollutants *viz.,* CO_2, NO_2, CH_4. SO_2 and VOC's emitted due to burning of agricultural crop residues (Zhang et al. 2011; Irfan el al. 2014; Jain et al. 2014).

Nitrous Oxide (NO_2)

The NO_2 concentration in the ambient air before burning of trash was ranging from 7.09 to 8.10 µg M^{-3}. However, the significantly increased concentration of NO_2 during *in situ* burning of sugarcane trash was ranging from 42.40 to 50.20 µg M^{-3}. It was reported that the concentration of NO_2 was increased by 6 times during burning of sugarcane trash. Similarly, the range of NO_2 before burning and during burning scenario was 1.01 and 7.80 µg M^{-3}, respectively. The baseline ambient air quality showed average value of 7.66 µg M^{-3}. However, during *in situ* burning of sugarcane trash NO_2 levels were increased up to average value 47.03 µg M^{-3}. During combustion of the organic matter

the total N content from the sugarcane trash was reported in the range of 0.42 to 0.58 per cent. The concentration of NO_2 was increased due to oxidation of nitrogen content in the sugarcane trash. However, the total N content from sugarcane trash ash was below detectable level. Guoliang et al. (2008) reported increased NO_2 emission after burning of agricultural residues. Similar results were also reported by Yang el al. (2008) who observed that the NO_2 emission were increased by 7.8 per cent in summer season due to burning of crop residues.

Sulphuer Oxide (SO_2)

The data on SO_2 revealed that, the range of SO_2 was 17.20 to 20.60 µg M^{-3} before *in situ* burning of sugarcane trash. However, the concentration of SO_2 was increased during *in situ* burning of sugarcane trash from 20.10 to 29.40 µg M^{-3}. In the current investigation, the SO_2 level was found increased. Similarly, Mittal et al. 2009 reported the SO_2 and NO_2 concentrations in the ambient air significantly increased after burning of crop stubbles during winter season. The value of total sulphur concentration content in sugarcane trash was lost up to 80 per cent due to *in situ* burning of sugarcane trash.

The drastic change in SO_2 level due to burning of rice residues also observed by Singh et. al., 2010.

Carbon Monoxide (CO)

The CO concentration in ambient air quality was reported below 5 ppm at all 15 locations before burning of sugarcane trash. The maximum range of CO concentration was 6.20 ppm, while minimum range of 4.70 ppm was reported during burning *in situ* of sugarcane trash at all the selected locations. The higher concentration of CO was majorly due to *in situ* burning of sugarcane trash. The higher values of CO were reported after burning of sugarcane trash. However, baseline study showed CO level below detection limit. This study indicated that the increased levels of CO due to *in situ* burning of sugarcane trash. These results are corroborated with the findings of Sahai et al. 2011; Irfan et al. 2014; Jain et al, 2014 and indicated that the increased concentrations of CO mainly due to burning of crop residues.

Methane (CH_4)

The concentration of CH_4 in ambient air quality before burning of sugarcane trash was reported below 0.2 ppm at all the locations. However, the values depicted during burning of trash were significantly increased to 0.5 ppm. The consistently CH_4 concentration was reported in the range of 0.5 ppm at all the sampling locations. During burning of sugarcane trash CH_4 concentrations in the ambient air was increased by 2 fold as compared to base line methane concentrations. The increased level of methane due to *in situ* sugarcane trash burning might be due to oxidation of organic matter in the process of combustion. These results are similar to those reported by Venkatraman et al. 2006;, Zhang et al. 2011; Jain et al. 2014.

Total volatile organic carbon (Total VOC's)

The total volatile organic compounds comprise toluene, benzene and xylene in ambient air quality at all the 15 locations. Before burning of sugarcane trash the total volatile organic compounds were below detectable limit. However, the total VOC's reported in the range of 1 to 1.09 ppm during the course of *in situ* burning of sugarcane trash. The rise in total VOC's concentrations was mainly due to burning of sugarcane trash. The increased levels of total VOC's might be due to combustion of organic matter from sugarcane trash during the process of *in situ* burning. These results are similar to those reported by Yang et al. 2008; Zhang et al. 2011 who found that the volatile organic compounds and semi volatile organic compounds were emitted during burning of agricultural residues.

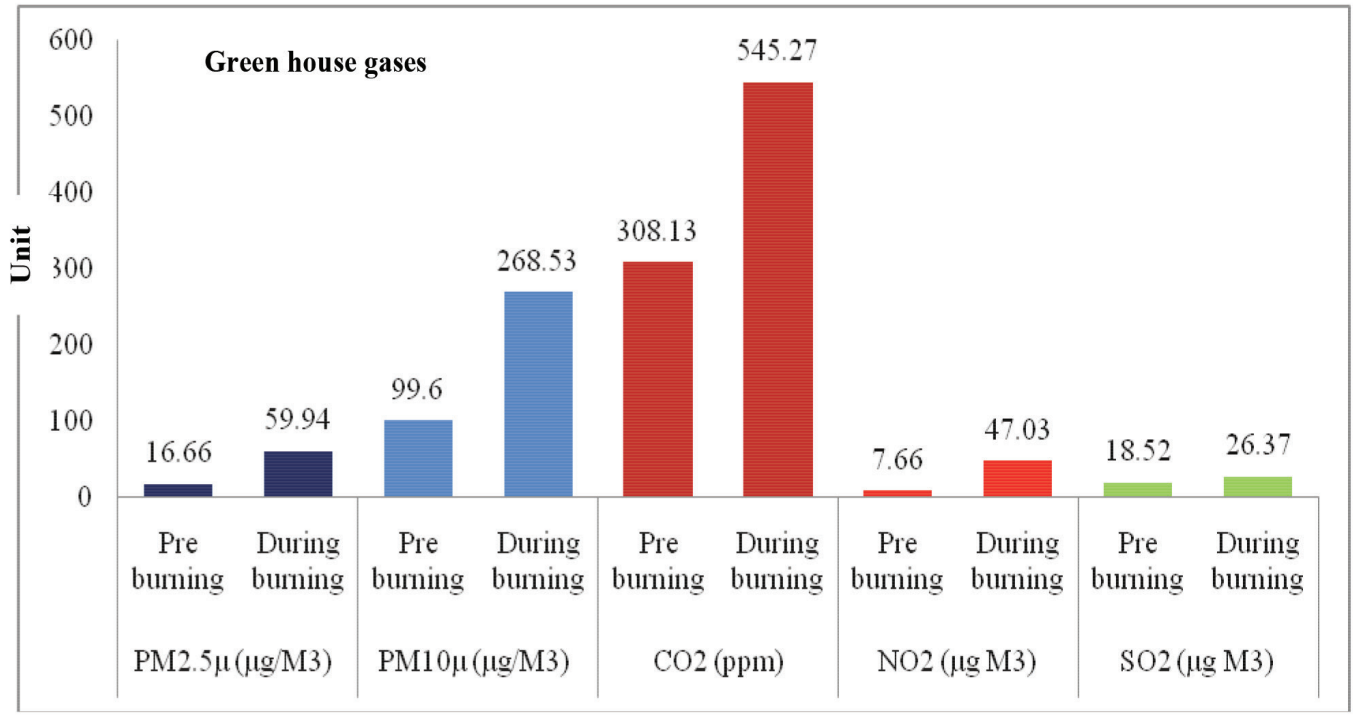

Figure 1 : Ambient air quality as influenced by *in situ* sugarcane trash burning

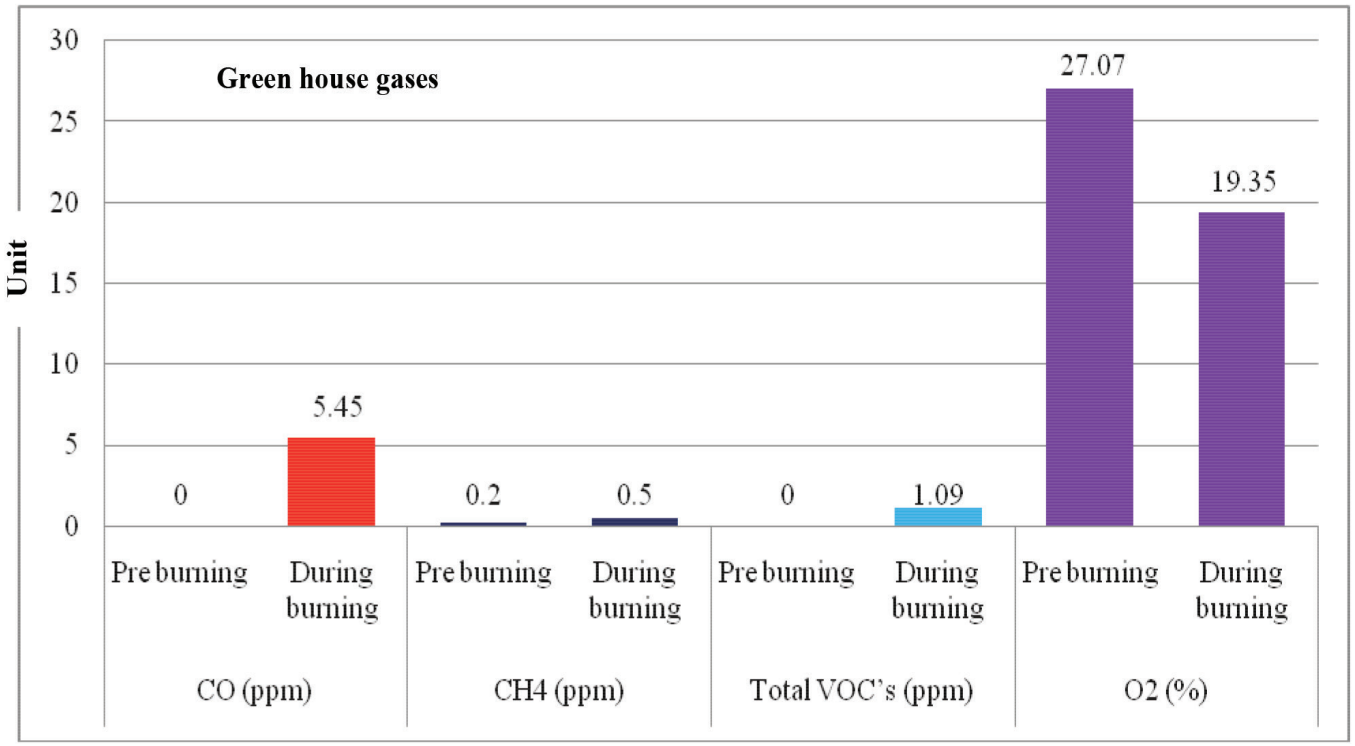

Figure 2 : Ambient Air Quality as Influenced by *In Situ* Sugarcane Trash Burning

Oxygen (O_2)

The O_2 level in the ambient air quality of selected sampling locations were found in the range of 20.1 to 20.8 per cent before burning of the sugarcane trash. However, the concentration of oxygen was reduced to 18.5 to 19.80 per cent during *in situ* burning of sugarcane trash. The major change in oxygen concentration of ambient air quality was reported before and during trash burning scenario. The oxygen level in the ambient air quality during burning of sugarcane trash and before burning of sugarcane trash (during base line) was 27.07 and 19.35 per cent, respectively. The depletion in the oxygen level in ambient air during burning of sugarcane trash was mainly due to oxidation of organic matter during the process of combustion. The nutrient analysis of sugarcane trash and its ash, calorific value and emissions clearly indicated that during oxidation process the total organic matter is being converted into greenhouse gases. These results are similar to those reported by Yang et. al. 2008.

Effect of* in situ *sugarcane trash burning on calorific value of sugarcane trash

The calorific value of sugarcane trash was found in the range of 1498 to 2023 kcal kg^{-1} with the average of 1805.73 kcal kg^{-1}. Calorific value of sugarcane trash was estimated under laboratory condition (*ex situ*) by combustion of sugarcane trash by using bomb calorimeter. The calorific value of agricultural residues ranging from 1500 to 1670 kcal kg^{-1} reported by Awulu et. al., 2023. The maximum calorific value of sugarcane trash was found to be 2023 kcal kg^{-1} with average value 1805.73 kcal kg^{-1} and this calorific value is highest among all other agricultural residues.

Table 5 : Location wise calorific value of sugarcane trash

Sample No.	Calorific value (cal g^{-1})
L_1	1745
L_2	2023
L_3	2015
L_4	1801
L_5	1545
L_6	1675
L_7	1889
L_8	1823
L_9	1805
L_{10}	1955
L_{11}	1836
L_{12}	1846
L_{13}	1645
L_{14}	1985
L_{15}	1498
Mean	1805.73
SE (±)	41.66
Max	2023.00
Min	1498.00
Range	525.00

Table 4 : Effect of *in situ* sugarcane trash burning on ambient air quality (green house gas emission)

Location	Air quality parameters																	
	$PM_{2.5\mu}$ ($\mu g/M^3$)		$PM_{10\mu}$ ($\mu g/M^3$)		CO_2 (ppm)		NO_2 ($\mu g\ M^3$)		SO_2 ($\mu g\ M^3$)		CO (ppm)		CH_4 (ppm)		Total VOC's (ppm)		O_2 (%)	
	Pre burning	During burning	Pre burning	During burning	Pre burning	During burning	Pre burning	During burning	Pre burning	During burning	Pre burning	During burning	Pre burning	During burning	Pre burning	During burning	Pre burning	During burning
L_1	15.25	63.2	90.2	256	290	512	7.13	42.4	17.4	28.2	<5	5.0	<0.2	<0.5	N.D	1.00	20.1	19.8
L_2	16.7	55.8	104	247	295	568	7.25	46.2	19.4	29.4	<5	4.9	<0.2	<0.5	N.D	1.01	20.4	19.1
L_3	18	56.1	106.1	268	313	549	7.09	48.4	20.6	29.4	<5	5.5	<0.2	<0.5	N.D	1.04	20.1	19.8
L_4	17.1	57.2	95.45	243	323	536	8.10	50.2	17.2	20.6	<5	5.7	<0.2	<0.5	N.D	1.18	20.3	18.5
L_5	17.4	63.2	97.1	288	308	514	8.02	49.1	17.4	27.2	<5	5.5	<0.2	<0.5	N.D	1.12	20.1	19.8
L_6	16.2	64.1	95.4	242	325	544	7.83	44.5	19.1	27.4	<5	5.3	<0.2	<0.5	N.D	1.15	20.1	19.6
L_7	15.9	59.3	93.7	279	289	523	8.08	46.4	20.0	29.1	<5	5.2	<0.2	<0.5	N.D	1.03	20.3	19.7
L_8	16.7	60.1	105.4	255	292	535	7.98	43.5	18.5	22.0	<5	5.1	<0.2	<0.5	N.D	1.16	20.1	19.7
L_9	17.6	57.2	106.2	262	300	549	7.75	45.6	18.4	28.5	<5	5.9	<0.2	<0.5	N.D	1.04	20.2	18.5
L_{10}	16.9	56.1	105.4	271	308	555	7.13	49.4	19.1	28.4	<5	4.7	<0.2	<0.5	N.D	1.19	21.0	18.9
L_{11}	15.3	62.4	93.7	289	313	532	7.20	48.3	17.3	20.1	<5	5.6	<0.2	<0.5	N.D	1.15	20.5	19.5
L_{12}	17.2	62.8	95.6	274	327	572	7.45	47.4	18.2	27.3	<5	5.4	<0.2	<0.5	N.D	1.08	20.6	18.7
L_{13}	16.8	61.9	93.9	280	298	541	7.92	44.7	17.7	28.2	<5	5.7	<0.2	<0.5	N.D	1.10	20.8	19.7
L_{14}	16.4	60.3	107.6	285	314	569	7.93	50.2	19.0	27.7	<5	6.0	<0.2	<0.5	N.D	1.06	20.6	19.5
L_{15}	16.5	59.4	104.3	289	327	580	8.05	49.1	18.5	22.0	<5	6.2	<0.2	<0.5	N.D	1.11	20.9	19.4
Mean	**16.66**	**59.94**	**99.60**	**268.53**	**308.13**	**545.27**	**7.66**	**47.03**	**18.52**	**26.37**	**-**	**5.45**	**-**	**-**	**-**	**1.09**	**27.07**	**19.35**
...	0.20	0.75	1.55	4.35	3.52	5.39	0.10	0.64	0.26	0.86	-	0.11	-	-	-	0.02	6.67	0.12
Max	18.00	64.10	107.60	289.00	327.00	580.00	8.10	50.20	20.60	29.40	-	6.20	-	-	-	1.19	20.40	19.80
Min	15.25	55.80	90.20	242.00	289.00	512.00	7.09	42.40	17.20	20.10	-	4.70	-	-	-	1.00	20.10	18.50
Range	2.75	8.30	17.40	47.00	38.00	68.00	1.01	7.80	3.40	9.30	-	1.50	-	-	-	0.19	00.30	1.30
SEm (±)	0.55		3.26		0.27		-		-		-		4.55		0.46		4.71	
CD at 5%	1.60		9.45		NS		-		-		-		13.17		1.33		NS	

CONCLUSION

The significant loss of nutrients present in sugarcane trash was recorded after *in situ* burning. Current study clearly indicated that due to potential nutrient composition and higher calorific value, the organic matter content of sugarcane trash is being converted into greenhouse gases during process of burning. Air pollution by greenhouse gases viz., PM2.5µ, PM10µ, CO_2, NO_2, SO_2, CO, CH_4 and total VOC's was observed with reduction in O_2 level in ambient air due to *in situ* sugarcane trash burning. The *in situ* sugarcane trash burning adversely affected soil microflora viz., bacteria, fungi and actinomycetes from 5 cm soil depth, significantly increased soil temperature with significant reduction in soil moisture as well as soil available nitrogen.

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