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Effect of Gas Flaring on Physico-Chemical Properties of Soil under Tea Plantation in Assam, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author KB and RK was responsible for performing the experiment, data collection, statistical data analysis, interpretation of the results and manuscript preparation. Authors SCB, GKS and NB conceived the idea. Author KB designed the experiment and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Gas flaring is a major contributor to the emission of toxic gases and other gaseous pollutants into the atmosphere. A study was undertaken to establish gas flaring effects on physic-chemical properties of soil under tea plantation in Assam, India. The experimental plot was laid out in 5 x 2 factorial RCBD. The experiment was carried out in small tea grower's gardens adjacent to OCS-6 at Merbil Majuli and Kothaloni OCS in Dibrugarh district of Assam in the year 2019-20. The experimental plots were laid out at 11 metres away from the gas flaring point. Plots were selected at an interval of 20 metres within the experimental design i.e. D_1 (11-31m), D_2 (31-51m), D_3 (51-71m), D_4 (71-91m) and D_C (150-170m) where, D_C denotes control plot. Soil samples for the study were obtained for two tea growing season i.e. rainy and autumn season from the selected gardens. Soil physical parameters such as bulk density, porosity, hydraulic conductivity, soil temperature and soil moisture and chemical parameters such as pH, organic carbon content, available NPK and electrical conductivity of both effected and control plots were evaluated in the laboratory to check the effect of gas flaring and the results obtained were compared with those from the control plot. The results showed that the soil temperature, soil moisture content, soil organic carbon and

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available NPK of both Merbil Majuli and Kothaloni were significantly affected by gas flaring with respect to distances. But, the bulk density, soil porosity, hydraulic conductivity, soil pH and electrical conductivity of soil were not affected by gas flaring.

Keywords: Gas flaring; tea soil; soil temperature; soil moisture; available NPK.

1. INTRODUCTION

Gas flaring is done for the easy disposal of the products of oil drilling operations. It is burning of natural gas and other petroleum hydrocarbons in flare stacks. When gas is burnt, a number of combustible products are formed. Gas stream leaks out of the open territories which includes essentially of methane which is entirely ignitable and form explosive mixtures once exposed to the outside. Most flaring processes usually take place at the top of stack by burning of gases with the visible flame [1-5]. Smoking flare may be a significant contributor to overall particulate emissions. Most flaring processes usually take place at the top of stack by burning of gases with the visible flame. It also results in production of excessive heat in the nearby areas.

Gas flaring is likely to affect adversely physical, chemical and biological properties of soil. Soil properties such as pH, organic carbon content, major nutrient content viz. N, P and K and dehydrogenase enzyme activity are reported to be affected by gas flaring [6]. Along with physico-chemical properties of soil, gas flaring also significantly affects the microclimate of soils at the flare sites [1]. Flaring may further contribute to local and regional environmental problems, such as acid rain with added impact on agriculture, forests and other physical infrastructure [7,8,9,10,11]. The acid rain results in environmental degradation including soil and water contamination.

In upper Assam oil fields, large quantities of gas keep on spouting out from the oil fields every day. A small fraction of this gas is used in factories for manufacture of tea, in generation of electricity and domestic purposes and the rest is flared out. The harmful effect of flaring is widespread, particularly its effects in the ecosystem. Investigation of different scientists on impact of gas flaring on soil health revealed that flaring and venting of related gas contributed to greenhouse gas emissions with negative effects on the earth [12].

Recently, specific attention is received in paddy and tea plantation, since most of the oil fields are located in tea and paddy growing belts. But little research works have been done on this aspect. There is an urgent need to study the impact of gas flaring on tea plantation with a holistic approach to find a solution to this problem. Therefore, through this research work an attempt has been made to study the impact of gas flaring released from the nearby oil fields on soil physico-chemical properties under tea plantations adjacent to oil field.

2. MATERIALS AND METHODS

Soil samples were collected from tea growing areas adjacent to Merbil Majuli OCS-6 and Kothaloni OCS, Dibrugarh, Assam, India in the year 2019-20.

Table 1. Description of study sites

Location		**Merbil Majuli OCS-6**	**Kothaloni OCS**
Map Coordinates	**Latitude**	27°19'24"N	27°37' N
	Longitude	95°17'54"E	95°09' E
	Altitude (Above mean sea level)	108 m	108 m
Average rainfall (mm)		191.62	196.4
Average Max. Temp. (^{O}C)		30.42	29.40
Average Min. Temp. (^{O}C)		18.98	19.30
Soil Type		Sandy Loam	Sandy Loam

Experiment design RCBD with 5 distances and 3 replications was laid out in both the locations. Collection of soil samples were carried out in two seasons viz. Rain flush (S_1) and Autumn flush (S_2). In each season samples were collected at four distances from the flare site with an interval of 20 m at distances D_1 (11-31m), D_2 (31-51m), D_3 (51-71m) and D4 (71-91m) starting from the gas flaring point in Merbil Majuli OCS-6 and Kothaloni OCS. Soil sample was also collected from control plot observed at D_C (150-170m) from the flare point.

Period of experiment	2019-20
Design	(5 x 2) Factorial RCBD
Number of factors	2 (season and distance)
Number of levels	2 level of season and 5 level of distance
Number of replication	3

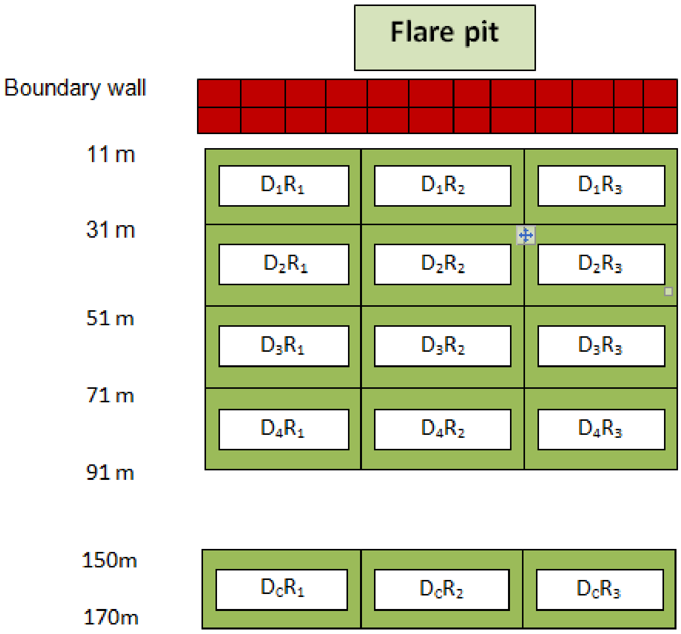

Fig. 1. Layout of Experimental plot

For sampling purpose, soil was collected from a depth of 0-30 cm from the ground level by an auger after removal of weeds or debris present on the soil surface. The laboratory works were carried out in the Department of Tea Husbandry & Technology, Assam Agricultural University, Jorhat-13, Assam, India.

2.1 Soil Physical Properties

2.1.1 Bulk density

For determining bulk density the gravimetric method was used, as described by Blake and Hartge, 1986 [13]. The determination of bulk density consists of drying (105°C) and weighing a soil sample, the volume of which is known (core method) or must be determined. It is expressed in Mg m^{-3}.

$$\text{BulkDensity} = \frac{\text{Weight of dry soil (Mg)}}{\text{volume of dry soil } (m^{-3})}$$

2.1.2 Porosity

Total porosity was determined by using Keen Rackzowski box following the method as described Baruah and Borthakur (1997) [14]. It is expressed in terms of ratio or percentage

$$f = Vf/Vt$$

Where, f = porosity, Vt = soil bulk volume and Vf = volume of the pores

2.1.3 Hydraulic Conductivity

Hydraulic conductivity was determined by the constant head parameter using undisturbed soil core samplers as described by Baruah and Borthakur(1997) [14] and expressed as cm min-1 as shown below:

$$KS = QL/At\ \Delta H$$

Where, KS = Hydraulic conductivity, Q = Volume of water collected (cm^3), L = Length of soil column (cm), A = Cross sectional area of the soil column (cm^2) equivalent to area of core, t = Time (minute), ΔH = Hydraulic head difference (cm).

2.1.4 Soil temperature

Soil temperature was measured by using soil thermometer (Luster Leaf 1625 Digital Soil Thermometer).

2.1.5 Soil moisture

The amount of water is determined by subtracting the dry weight from the initial weight, and the moisture content is then calculated as the amount of water divided by the dry weight.

2.2 Soil Chemical properties

2.2.1 Soil pH

Determination of soil pH was conducted using a glass electrode pH meter (Eutech pH 700), Jackson (1973) [15].

2.2.2 Organic carbon content

Soil organic carbon was determined by using Titrimetric determination [11] and was expressed in percentage.

2.2.3 Electrical conductivity

Electrical conductivity of the soil was measured at a soil: water ratio of 1:2.5 by the help of EC meter [15] and was expressed as deciSiemens/metre (dSm^{-1}).

2.2.4 Available nitrogen

The estimation of available nitrogen was done by Kjeldahl's method as described by [15].

2.2.5 Available phosphorous

The estimation of available phosphorous was determined by Bray's method as described by [15] and was determined in kg ha^{-1}.

2.2.6 Available potassium

The estimation of Available potassium was determined by extracting the soil with ammonium acetate and the potassium is determined by flame photometric method as described by [15].

3. RESULTS AND DISCUSSION

3.1 Soil Physical Parameters

3.1.1 Bulk density

Bulk density of soil of both Merbil Majuli and Kothaloni had no significant variation ($p \geq 0.05$) for both distances and seasons from the gas flaring site (Tables 2 & 3).

3.1.2 Soil porosity

Soil porosity of both the locations had no significant variation ($p \geq 0.05$) for both distances and seasons from the gas flaring site (Tables 2 & 3).

3.1.3 Hydraulic conductivity

Hydraulic conductivity of soil of both the locations had no significant variation ($p \geq 0.05$) for both distances and seasons from the gas flaring site (Tables 2 & 3).

3.1.4 Soil temperature and soil moisture

Soil temperature at both the locations varied significantly ($p<0.05$) for different distances from the gas flaring site but no significant variation ($p \geq 0.05$) was observed among the seasons at Merbil Majuli, during both rainy season (S_1) and autumn season (S_2). The soil temperature was recorded lowest (25.23^{o}C & 26.22^{o}C) at distance D_C (150-170 m), whereas highest (29.33^{o}C & 30.33^{o}C) was recorded at distance D_1 (11-31m). In case of Kothaloni during both rainy and autumn season the soil temperature was recorded lowest (26.77^{o}C & 27.00^{o}C) at distance D_C (150-170m), whereas highest (29.33^{o}C & 29.00^{o}C) was recorded at distance D_1 (11-31m) (Tables 2 & 3). The increase in temperature observed near the gas flaring site may be due to the dark colour of the soil which absorbs more heat [16].

Soil moisture varied significantly ($p<0.05$) with distance from the gas flaring site but no significant variation ($p \geq 0.05$) was observed among the seasons. At Merbil Majuli, the soil moisture was recorded lowest (11.71% & 11.93%) at distance D_1 (11-31 m) at both the seasons, whereas highest (15.55% & 14.26%) was recorded at distance D_C (150-170 m) at both the seasons. In Kothaloni the soil moisture was recorded lowest (11.51% & 11.37%) at distance D_1 (11-31m) during both rainy (S_1) and autumn season (S_2), whereas it was recorded highest (15.38% & 15.32%) at distance D_C (150-170m) (Tables 2 & 3).

The estimation of soil moisture and temperature is critical to the understanding of land surface–atmosphere interactions. The study revealed that soil temperature varies significantly ($P<0.05$) among the different distances from the flare pit. Higher light intensities were recorded in distance closer to the flare and it decreases on moving away from the flare [3]. Although the air temperature outside the boundary wall was relatively low due to the insulating effect of the concrete walls, the mean soil temperatures varied between D_1 and D_C in the experimental fields. Since the flare intensity varies with distance from flare (Sharma *et al.,* 2011), it demarcates the increase in soil temperature in distance near the flare. The results fit the observation of [3,2,6,17,18].

The mean soil moisture level was also significantly ($P<0.05$) different in all the different distances from the flare. The decrease in soil moisture corresponds with the increase in soil temperature. The relationship between soil temperature and moisture follow an inverse relationship, i.e., when the soil temperature increases, the soil moisture decreases (Fig. 2). Similar observation was also made by [19,20] where it was inferred that soil temperature shows an increase that corresponds to a decrease in the soil moisture.

3.2 Soil Chemical Parameters

3.2.1 Soil pH

Soil pH of both Merbil Majuli and Kothaloni had no significant variation ($p\geq0.05$) for both distances and seasons from the gas flaring site (Tables 4 & 5).

3.2.2 Electrical conductivity

Electrical conductivity of soil of both Merbil Majuli and Kothaloni had no significant variation ($p\geq0.05$) for both distances and seasons from the gas flaring site (Tables 4 & 5).

3.2.3 Soil organic carbon, Available nitrogen, Available phosphorus and Available potassium

Soil organic carbon varied significantly ($p<0.05$) at various distances from the gas flaring site but no significant variation ($p\geq0.05$) was observed among the seasons. At Merbil Majuli the soil organic carbon was recorded lowest (0.80% & 0.79%) at distance D_1 (11-31 m) at both the seaosns, whereas highest (0.87% & 0.85%) was recorded at distance D_C (150-170 m). In Kothaloni the soil organic carbon was recorded lowest (0.82% & 0.82%) at distance D_1 (11-31m) and highest (0.83% & 0.85%) at distance D_C (150-170m) for both seasons (Tables 4 & 5).

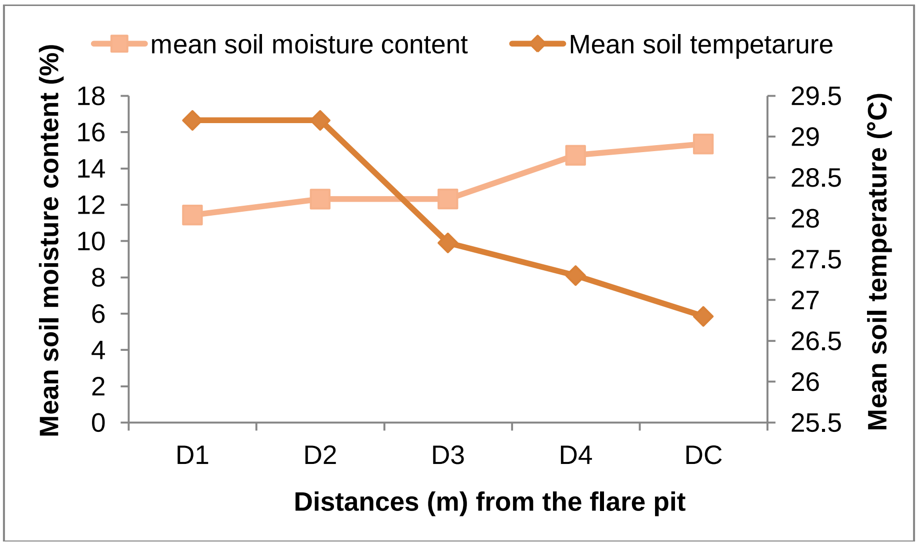

Fig. 2. Mean soil temperature (°C) and mean soil moisture (%) of tea soils influenced by different distances from flare pit

Available nitrogen in soil showed significant variation ($p<0.05$) for distances from the gas flaring site but no significant variation ($p \geq 0.05$) was observed among the seasons. At Merbil Majuli during both rainy season (S_1) and autumn season (S_2) the available nitrogen in soil was recorded lowest (245.66kg/ha & 242.66 kg/ha) at distance D_1 (11-31 m), whereas highest (255.00 kg/ha & 252.00 kg/ha) was recorded at distance D_C (150-170 m). For rainy and autumn season at Kothaloni the available nitrogen was lowest (242.00kg/ha & 244.00 kg/ha) at distance D_1 (11-31m) and highest (245.33kg/ha & 245.67 kg/ha) at distance D_C (150-170m) at rainy and autumn seasons (Tables 4 & 5).

Available phosphorus in soil varied significantly ($p<0.05$) at various distances from the gas flaring site but no significant variation ($p \geq 0.05$) was observed among the seasons. At Merbil Majuli, during rainy season (S_1) and autumn season (S_2) the available phosphorus in soil was recorded lowest (13.80kg/ha & 13.81 kg/ha) at distance D_1 (11-31m), whereas highest (14.88 kg/ha & 14.85 kg/ha) was recorded at distance D_C (150-170 m). In Kothaloni the available phosphorus was recorded lowest (14.04kg/ha & 14.09kg/ha) at distance D_1 (11-31m) and highest (14.11kg/ha & 14.13kg/ha) at distance D_C (150-170m) at rainy and autumn season (Tables 4 & 5).

Available potassium in soil varied significantly ($p<0.05$) at various distances from the gas flaring site but no significant variation ($p \geq 0.05$) was observed among seasons. At Merbil Majuli, during both rainy season (S_1) and autumn season (S_2) the available potassium in soil was recorded lowest (255.00 kg/ha & 254.33 kg/ha) at distance D_1 (11-31m), whereas highest (269.44 kg/ha & 267.25 kg/ha) was recorded at distance D_C (150-170m). In Kothaloni the available potassium was recorded lowest (251.67 kg/ha & 252.67kg/ha) at distance D_1 (11-31m) and highest (256.00 kg/ha & 261.33 kg/ha) at distance D_C (150-170m) at rainy and autumn season (Tables 4 & 5).

Table 2. Effect of gas flaring on soil physical parameters of Merbil Majuli OCS-6

	Bulk Density (Mg/m^3)		Soil Porosity (%)		Hydraulic conductivity (cm/min)		Soil Temperature (^oC)		Soil Moisture (%)	
Distances	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
$\mathbf{D_1}$(11-31 m)	1.22	1.23	45.00	44.10	0.33	0.32	29.33	30.33	11.71	11.93
$\mathbf{D_2}$(31-51 m)	1.21	1.22	45.00	45.13	0.31	0.32	28.66	29.00	12.32	12.30
$\mathbf{D_3}$(51-71 m)	1.22	1.22	46.23	46.06	0.31	0.32	27.33	27.66	12.88	11.75
$\mathbf{D_4}$ (71-91 m)	1.21	1.21	47.20	47.14	0.31	0.32	26.33	26.66	15.47	14.16
$\mathbf{D_C}$ (150-170 m)	1.22	1.21	48.25	48.10	0.30	0.31	25.33	26.22	15.55	14.26
CD(factor D)	NS		NS		NS		0.857		1.742	
CD(factor S)	NS		NS		NS		NS		NS	

**Significant at 5% probability level*

Table 3. Effect of gas flaring on soil physical parameters of Kothaloni OCS

	Bulk Density (Mg/m3)		Soil Porosity (%)		Hydraulic conductivity (cm/min)		Soil Temperature (^oC)		Soil Moisture (%)	
Distances	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
$\mathbf{D_1}$(11-31 m)	1.19	1.18	46.06	46.67	0.32	0.33	1.19	1.18	46.06	46.67
$\mathbf{D_2}$(31-51 m)	1.18	1.19	46.73	46.76	0.32	0.32	1.18	1.19	46.73	46.76
$\mathbf{D_3}$(51-71 m)	1.20	1.19	46.33	45.97	0.32	0.31	1.20	1.19	46.33	45.97
$\mathbf{D_4}$ (71-91 m)	1.20	1.17	46.67	48.33	0.32	0.31	1.20	1.17	46.67	48.33
$\mathbf{D_C}$ (150-170 m)	1.18	1.16	47.33	48.23	0.31	0.31	1.18	1.16	47.33	48.23
CD(factor D)	NS		NS		NS		0.655		1.88	
CD(factor S)	NS		NS		NS		NS		NS	

**Significant at 5% probability level*

Table 4. Effect of gas flaring on soil chemical parameters of Merbil Majuli OCS-6

	Soil pH		Soil Organic Carbon (%)		Electrical Conductivity (dS/m)		Available Nitrogen (kg/ha)		Available Phosphorus (kg/ha)		Available Potassium (kg/ha)	
Distances	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
D_1 (11-31 m)	5.00	4.92	0.80	0.79	0.35	0.34	245.66	242.66	13.80	13.81	255.00	254.33
D_2 (31-51 m)	5.13	5.07	0.81	0.80	0.40	0.36	248.66	247.00	14.36	14.27	257.00	257.00
D_3 (51-71 m)	5.15	5.19	0.85	0.83	0.32	0.30	251.66	248.00	14.39	14.82	264.00	262.00
D_4 (71-91 m)	5.19	5.11	0.85	0.84	0.29	0.27	254.00	249.33	14.87	14.82	269.00	267.00
D_C(150-170 m)	5.24	5.11	0.87	0.85	0.24	0.26	255.00	252.00	14.88	14.85	269.44	267.25
CD (factor D)	NS		0.02		NS		1.588		0.478		1.965	
CD (factor S)	NS		NS		NS		NS		NS		NS	

**Significant at 5% probability level*

Table 5. Effect of gas flaring on soil chemical parameters of Kothaloni OCS

	Soil pH		Soil Organic Carbon (%)		Electrical Conductivity (dS/m)		Available Nitrogen (kg/ha)		Available Phosphorus (kg/ha)		Available Potassium (kg/ha)	
Distances	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
D_1(11-31 m)	5.15	5.11	0.82	0.82	0.35	0.33	242.00	244.00	14.04	14.09	251.67	252.67
D_2(31-51 m)	4.97	4.98	0.82	0.84	0.39	0.35	243.00	252.00	13.90	14.22	260.00	262.00
D_3(51-71 m)	5.18	5.14	0.83	0.80	0.31	0.30	241.33	249.33	14.43	14.03	254.67	257.33
D_4 (71-91 m)	5.11	5.03	0.81	0.83	0.27	0.27	249.33	277.00	14.03	14.14	256.33	259.00
D_C (150-170 m)	4.97	5.04	0.83	0.85	0.39	0.30	245.33	245.67	14.11	14.13	256.00	261.33
CD (factor D)	0.03		NS		1.590		0.465		1.955		0.03	
CD (factor S)	NS		NS		NS		NS		NS		NS	

Significant at 5% probability level

Soil organic carbon content was low for both Merbil Majuli OCS-6 and Kothaloni OCS near the flaring point and increases significantly away from the flaring point. This might be due to the less return of plant residues into soil closer to the flare stack, due to which the return of nutrients to the soil got reduced resulting in an impoverished soil [21] and available NPK in the soil was recorded low for Merbil Majuli OCS-6 and Kothaloni OCS near the flaring site and increases away from the flaring site. Soil organic matter content influences the soil NPK content. Low soil organic matter content was observed in distances nearer to the flare site as a result the level available NPK in the soil was also low in distances near the flare. The acidic condition of the soil and induced decomposer microbial activity in the flare zone also affects the available NPK content of the soil [22,16].

4. CONCLUSION

The present investigation revealed that the gas flaring had significant effect on some physical and chemical properties of tea soil i.e. soil temperature, soil moisture, soil organic carbon and available NPK beyond 71m and 91m from the gas flaring point and some other properties of soil such as bulk density, soil porosity, hydraulic conductivity, soil pH and electrical conductivity were not affected by gas flaring at any distance from the flaring point. The study is inconclusive about affect of gas flaring on total soil health for over a longer period of time. It needs to be studied thoroughly with a holistic approach.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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