Impact of oil field effluent on some physico-chemical properties of soil, quality and growth of Tea in the plantation of small growers of Dibrugarh, Assam

ABSTRACT

Aims: To study the impact of the oil field effluents discharged to the plantation on soil physicochemical, quality and growth of the tea crop.

Study design: The experimental design was 4x2 Factorial Randomized Block Design with 3 replications.

Place and Duration of Study: It was conducted in Department of Tea Husbandry & Technology, Assam Agricultural University, Jorhat during September, 2019 and November, 2019.

Methodology: The total number of bushes per treatment are 35 each of +12 years age. The soil and plant samples were collected from four different levels of distance are D1: 0-21m; D2: 21-42m; D3: 42-63m and DC: beyond 63m (Control).

Results: The results showed that, disregarding the Flushing season the tea grown in the vicinity of the oil pit recorded the lowest value of caffeine content (1.58%), total chlorophyll (1.54 mg g^{-1}) total polyphenol content (21.47%) which was significantly lower than the tea grown away from the oil pit. The plucking point density and number of primaries per plant recorded the lowest value in the vicinity of the effluent pit. In case of soil physical parameters, both porosity and hydraulic conductivity recorded lowest value of 45.64% and 0.25 cm min^{-1}, respectively. The bulk density of soil near the oil effluent pit recorded the highest value (1.31 Mg m^{-3}) and gradually decreases. Soil pH, organic carbon content and electrical conductivity recorded highest value in the vicinity of the effluent pit. Regardless of the flushing season the available nitrogen and potassium recorded the highest. Available phosphorous of the soil adjacent to the effluent pit recorded the lowest value. Both quality and growth parameters had significantly higher value in the rain flush than the autumn flush. The soil parameters did not record any significant variation among the seasons.

Conclusion: The vicinity area of the effluent pit found to be the most vulnerable.

Keywords: oil field effluent, effluent pit, rain flush, autumn flush

1. INTRODUCTION

The Assam tea is cultivated in the valley of the Brahmaputra River, an area of clay soil rich in the nutrients of the floodplain. Assam is one of the most prolific tea producing regions in the world because of its long growing season and generous rainfall. The Tea gardens are mostly found in some of the districts of Assam like Tinsukia, Dibrugarh, Moran, Sivasagar, Jorhat, Sonitpur, Darrang and Golaghat. The estimated annual average production of Tea in Assam is about 630-700 million kg. [1]

On the other hand, there are more than 100 oilfields in Assam. Some of the major oil fields of Assam: Digboi, Geleki, Dikom, Kothaloni, Baghjan, Borhola, etc. The crude oil production amounted to almost 4.3 million metric tons in Assam (During fiscal year 2019) [2]. The refineries in India generates about 28,220 tons of sludge per annum (3).

Assam is rich in both bio resources and natural resources, especially petroleum, natural gases and coal, tea and rice. Most of the oil drilling sites are located in the fringes of human settlements with paddy fields and tea gardens, resulting in hydrocarbon contamination. Crude oil drilling has severely degraded the land ecosystem in this zone and have had a negative impact on bio resources; i.e., tea plantation and rice cultivation. Emerging contaminants came to occupy the center of environmentalism since the 1960s primarily due to the groundbreaking work of Carson who, in her landmark book Silent Spring, presented an apocalyptic vision of a world made barren by them (4).

Studies around the world revealed that uptake of selected Polycyclic Aromatic Hydrocarbons (PAHs) from contaminated soils by rice seedlings (*Oryza sativa*) in a rice ecosystem in Jinxing of Zhejiang Province, China, focused on the facts that PAHs were taken up by rice roots via passive processes and that their uptake was correlated with concentrations of PAH in rhizosphere (5). Numerous studies have confirmed that the combination of these binary types of contaminants could present a great environmental threat to all biotic components of the ecosystem (6) and therefore the US Environment Protection Agency has ranked them (16 PAHs and Pb, As, Cr, Cd, Zn) among the top 12 contaminants of concern (7).

In South Central China, where 18 wild plant species were detected with simultaneous accumulation of PAHs and HMs from industrial contaminated sites, although disparities of PAHs and HMs in spatial distributions among sites was evident (8). The sites where accidental seepage occurs become desert like in nature and disturb the rice ecosystem. These activities directly lead to fragmented landscapes, loss of cultivated land and imbalances in beneficial soil microbes finally resulting in the overall loss of crop production and economic loss. The indirect effects can be loss of the water holding capacity of soil, imbalances in physicochemical properties, discharge of carcinogenic pollutants of ambient air and perennial water sources, loss of biodiversity and loss of economic wealth (9). Some of the technologies for remediation of the soil are phytoremediation, including species like *Boehmeria nivea* (L.) Gaudich, *Pteris vittata* (L.), *Pteris cretica* (L.) could be proposed as promising materials for heavy metal and PAHs combined pollution remediation; bioremediation, using living organisms like microbes and bacteria such as *Pseudomonas aeroginosa strains* AS 03 & NA 108; and chemical degreaser/detergent emulsions such as Trichloroethylene and Perchloroethylene.

Heavy metal pollution is a special great concern as heavy metals are difficult to biodegrade and liable to accumulate. Particularly, heavy metals are available to crops grown in acidic soils. Tea is an unusual crop because it is usually grows in acidic soil and its planting makes soil more acidic, which may urge accumulation of heavy metals in tea. This possibility necessitates a serious consideration of the impact of oil drilling sites on tea plantations near them, given the importance of tea in the state’s bioeconomy. Heavy metal concentration of soils in tea gardens has remained a concern in recent years.

Therefore, through this research work an attempt has been made to study the impact of the oil field effluents discharged to the plantation nearby oil fields with probable effect on soil physicochemical and the growth of the tea crop at Dibrugarh district of Assam.

2. MATERIAL AND METHODS

Site description

The experiment was laid out near Oil Collecting Station (OCS-2) and Well No. 17, 25, 30 and 44 in village No. 1 Shalmari of Moran in the district of Dibrugarh, Assam. The samples comprising of the tea plant were collected and studied in the department of Tea Husbandry & Technology, AAU, Jorhat, Assam during 2019-2020. Also some data were generated in experimental field. The latitude and longitude of the area was 27°11' N and 94°55' E, respectively.

2.1 Tea leaf samples and analysis

The fresh and tender tea leaves of TV 22 were collected from four different distances in two seasons i.e., rain flush and autumn flush. The total number of bushes per treatment are 35 each of +12 years age. The different levels of distance are D1: 0-21m; D2: 21-42m; D3: 42-63m and DC: beyond 63m (Control). The experiment followed an experimental design of 4 × 2 Factorial RBD. The experiment was replicated three times.

2.1.1 Quality Parameters

2.1.1.1 Caffeine content

A weight of 20 g of two leaves and a bud-shoots were taken in a 400 ml beaker and boiled with 200 ml of water for about 30 min and filtered while hot. The filtrate was collected in another clean beaker and added 10% aqueous solution of lead acetate followed by centrifugal at 5000 rpm for 5 minutes. The volume of the suspension was then reduced to 25 ml by boiling and cooled it to a room temperature. After cooling the reaction mixture was extracted with 25 ml chloroform in a separating funnel. Then distilled off chloroform from the chloroform extract on a water bath using a water condenser. Scraped the dry residue from the flask with a spatula and weighed it. The amount of caffeine was calculated by taking weight of fresh tea leaves and weight of crude caffeine in gram, then total caffeine in tea leaves was expressed in percentage.

2.1.1.2 Total polyphenol content

Estimation of polyphenols with Folin-Ciocatteu reagent is based on the reaction between phenols and an oxidizing reagent phosphomolybdate which results in the formation of blue complex (10).

The shoots were divided into three parts starting from the bud, first leaf and the second leaf. These parts were separated oven dried and crushed to make powder. From the crushed powder, 1 gm of sample was weighed accurately and extracted with 10 ml 80% ethanol. Centrifuged at 1000 rpm for 20 minutes and pooled the supernatant. After evaporating the supernatant to dryness dissolved the residue in 10 ml of distilled water. Then 0.5 ml of Folin-Ciocalteu reagent was added to 1 ml of extract followed by adding 2 ml of 20% sodium carbonate solution and mixed well. Then volume was made to 5.5 ml by adding 2 ml distilled water. Contents in the test tube were heated in a boiling water bath for 1 minute and cooled under running water and absorbance was measured at 650 nm in a spectrophotometer. A standard curve was prepared from different concentrations of Catechol. The value of total polyphenol was expressed in percent. Estimation was done on two occasions i.e., in rain flush and autumn flush.

2.1.1.3 Chlorophyll content

The two leaves and a bud shoot exposed to full sunlight were sampled and homogenized 0.5 g of tissue in a pestle and mortar with 25 ml of methanol under dark condition and centrifuged at 5000 rpm for five minutes. Then 2 ml of supernatant was diluted to 10 ml of methanol. The spectrometric observation of diluted solutions was recorded in three different wavelengths, *viz*, 470 nm for total Carotene (Tc), 653 nm for Chlorophyll-a and 666 nm for Chlorophyll-b.

2.1.2 Methods for plant growth parameters

2.1.2.1 Plucking point density

A grid divided into squares of 10 cm was placed on the top of the bush. The number of Plucking points considered are the points from where the shoots have already been plucked in 50 × 50 cm2 area (11).

2.1.2.2 Number of primaries

The number of primaries are counted from each of the light pruned sticks tagged earlier and the number of primaries reaching the tipping height was recorded.

2.2 Soil samples and analysis

The soils were collected from different levels of distances. The different levels of distances are as follow: D1: 0-21 m; D2: 21-42 m; D3: 42-63 m and DC: beyond 63m (Control).

2.2.1 Physical properties

Table 1: Methods used for estimation of soil physical properties

Soil parameters	Unit	Method	Reference
Soil Bulk density	$Mg\ m^{-3}$	Gravimetric method using core samplers	15
Porosity	%	Keen Raczkowski box method	16
Hydraulic conductivity	$cm\ mm^{-1}$	Core sampler method	16
Soil particle analysis	%	Hydrometer method	16

2.2.2 Chemical parameters

Table 2: Methods used for estimation of soil chemical properties

Soil parameters	Unit	Method	Reference
Soil pH		pH meter	12
Electrical conductivity	Ds m^{-1}	Measured at a soil: water of 1: 2.5 by the help of EC meter	13
Organic carbon	g kg^{-1}	Walkley and black's titration	14
Available nitrogen	kg ha^{-1}	Kjeldahl's method (alkaline potassium permanganate)	12
Available phosphorous	kg ha^{-1}	Bray's method	12
Available potassium	kg ha^{-1}	Flame Photometric method	12

Statistical analysis

All the data pertaining to the present investigation statistically analyzed as per the method of analysis of variance (ANOVA) for (4×2) factorial RBD. The critical difference (C.D) values were calculated at 5% probability level. For analysis software OPSTAT1 and SPSS 7.5 were used.

3. RESULTS AND DISCUSSION

In Upper Assam several crude oil drilling sites are found in and around the tea plantation. The potential sources for releases of crude oil and its products to the soil are exploration, production, storage, refining and transportation etc. During the oil exploration the effluents released from different drilling activities are deposited in the effluent pits. Sometimes due to overloaded or seepage the effluents come in contact with the nearby crops. In this case due to seepage the tea plantation come in contact the oil effluents. As a result, crude oil contamination in such tea gardens is very much prevalent due to spillage, tank failures, transport and abandonment of drilling sites etc. Crude oil pollution has a significant impact on soil environment (17).

The present investigation was undertaken to study the impact of oil field effluent on some quality of tea, growth parameters of tea and soil physico-chemical properties of Shalmari area.

3.1. Tea leaf samples

3.1.1 Quality parameters

3.1.1.1 Caffeine content

The experimental data of total caffeine are presented in the Table 3 as influenced by distance from the effluent pit and the flushing seasons. The percentage of total caffeine was found to have altered significantly due to the distance of tea plots from the oil effluent pit. The control plots of tea (beyond 63m distance) recorded the highest value of total caffeine (2.62%) while the tea plots at the nearest distance (0-21m distance) from the pit contained the lowest value (1.58%). There was gradual but significant fall in the value of total caffeine as the level of distance was found to have approached nearer the pit. Drought stress inhibits the expression of genes related to caffeine biosynthesis, thereby reduced the accumulation of caffeine in *C. sinensis* leaves (18). In addition, under drought stress the total flavonoids content significantly increased which may be an important reason that drought stress affected the liquor colour of tea (19).

Percentage decrease of value of total caffeine on the other hand appeared to have fallen from -39.69% at 0-21m distance (nearest the pit) to -5.73% at 42-63m distance (farthest to the pit) over the control tea plots beyond 63m distance from the pit (Fig.1).

3.1.1.2 Total polyphenol content

Influence of the oil effluent on total polyphenol content of the tea leaf at different distances of the tea plot from the effluent pit during different flushes of tea crop is presented in Table 3 and the trend of decrease of the content of total polyphenol with respect to distance of the tea plot from the pit over control can be seen from Fig. 3.2. The tea plots at different level of distances from the pit appeared to have significant variation in the content of total polyphenol, the nearest plot at 0-21m distance being recorded the lowest value (21.47%) and the farthest plot at beyond 63m distance (control) registered the highest value (23.31%) of total polyphenol. The total polyphenol content of leaves decreased near the oil field effluent site and it gradually increases along with the distances away from the effluent pit. Drought stress reduced *C. sinensis* leaf quality as indicated by a significant decrease in total polyphenol (20). Plant polyphenols have gained prominence in quality of plant products and in human health. Declining soil water content (SWC) reduced both growth and content of polyphenols in tea (21). The results of this study indicated that declining soil water content limits growth of tea, and that there is an association between shoot growth and total polyphenol content.

Gradual and significant percentage decrease of total polyphenol over control in respect of distance of the tea plots from the pit are reflected by recording the greater decrease of total polyphenol (-7.89%) in the nearest plot towards the smaller decrease (-3.73%) in the farthest tea plot, (Fig. 2).

Seasonal variation in the content of total polyphenol was found to be statistically significant the rain flush tea being recorded the highest value (22.95%) and the autumn flush recorded the lowest in the oil effluent affected tea plantation.

Table 3: Impact of oil effluent on total caffeine (%) and Total Polyphenol content (%) of tea leaf during different flushing seasons

Flushing season / Distance	Total Caffeine (%)				Total Polyphenol content (%)			
	Rain Flush (S_1)	**Autumn Flush (S_2)**	**Mean Distance**		**Rain Flush (S_1)**	**Autumn Flush (S_2)**	**Mean Distance**	
0-21m (D_1)	1.62	1.55	1.58		22.62	20.33	21.47	
21-42m(D_2)	2.22	2.15	2.19		23.16	21.34	22.25	
42-63m(D_3)	2.53	2.41	2.47		22.71	22.16	22.44	
Beyond 63m (D_c)	2.56	2.68	2.62		23.32	23.29	23.31	
Mean Season	2.23	2.19			22.95	21.78		
Factors	**C.D.**	**SE(d)**	**SE (m)**	**Significance**	**C.D.**	**SE(d)**	**SE (m)**	**Significance**
Distance (D)	0.09	0.04	0.03	S	0.11	0.05	0.04	S
Flushing Season (S)	N/A	0.03	0.02	NS	0.08	0.04	0.03	S
Distance × Flushing season (D×S)	N/A	0.06	0.04	NS	0.16	0.07	0.05	S

*N/A:- Not Applicable, NS:- Non-significant, S:- Significant

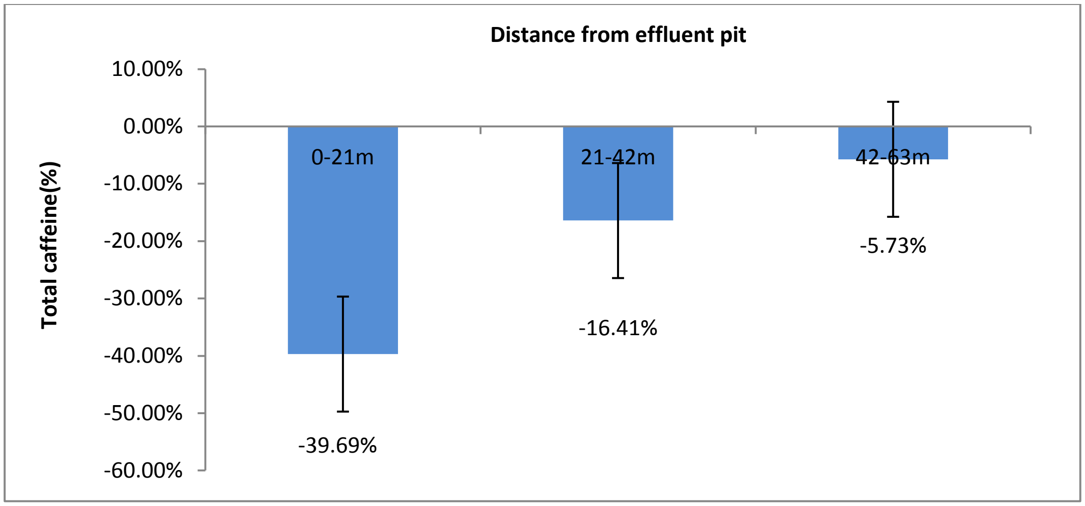

Fig 1: Graphical representation of percentage decrease of total caffeine (%) over control, influenced by distance

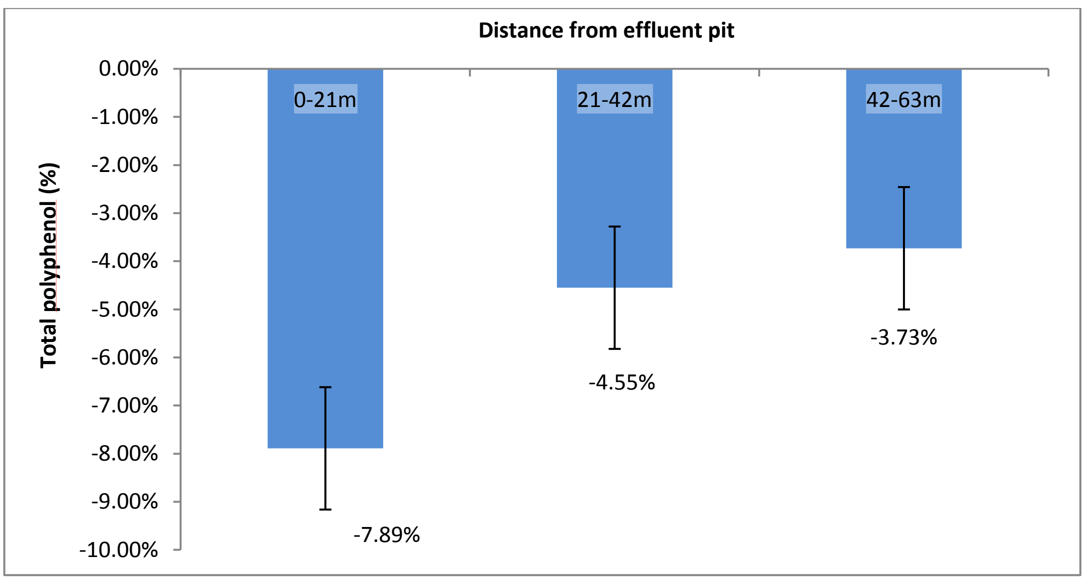

Fig 2: Graphical representation of percentage decrease of total polyphenol (%) over control, influenced by distance from the effluent pit

3.1.1.3 Chlorophyll Content

The tea leaf was found to record the lowest content of chlorophyll a (0.88 mg/gm fresh weight) and of chlorophyll b (0.56 mg g^{-1} fresh weight) in the tea plot at 0-21m distance from the oil field effluent pit and the highest content of chlorophyll a (1.10 mg g^{-1} fresh weight) and of chlorophyll b (0.92 mg g^{-1} fresh weight) in the tea plot at the farthest distance beyond 63m from the pit (control), Table 4 The mean content of total chlorophyll was found to be same in two plots of tea nearer to the oil effluent pit i.e. 0-21m distance and 21-42m distance (1.54 mg g^{-1} fresh weight) although the control tea plot was found to record the highest value (1.88 mg g^{-1} fresh weight). It was observed that total chlorophyll content decreases near the vicinity of oil effluent pit and it gradually increases along with distance away from the effluent pit.

Decrease in the total chlorophyll content in the leaves is perhaps due to the alkaline condition created by dissolution of chemicals present in the oil in the cell sap which was responsible for chlorophyll degradation. The total chlorophyll content of polluted leaves is lower than that of control leaves and was reported by several researchers (22,23,24). Crude oil induced environmental stress in the cowpea (*Vigna unguiculata*) seedlings and it was indicated by decrease in chlorophyll contents of the leaves of 12-day-old seedlings (25). Changes in the leaf Chlorophyll content of *Amorpha fruticosa* seedlings are affected by both the intensities of petroleum contamination stress and the alteration of stress time (26). Decreases in plant Chlorophyll contents due to petroleum-contaminated soil have already been reported and attributed to the direct toxic affects which petroleum exerted on plants (25, 27, 28). The oil effluent was found to have significant effect on two different tea flushes in respect of chlorophyll contents (Table 4). In the rain flush tea, the mean contents of chlorophyll a, and total chlorophyll were found to be significantly higher (1.02 mg g^{-1} fresh weight and 1.70 mg g^{-1} fresh weight, respectively) than the autumn flush tea (0.93 mg g^{-1} fresh weight and 1.63 mg g^{-1} fresh weight, respectively.

Table 4: Influence of oil effluent on chlorophyll a, chlorophyll b and total chlorophyll (mg g^{-1} fresh weight) of tea leaf at different distance from the pit during different flushing seasons in Shalmari area.

Flushing Season	Chlorophyll a (mg g^{-1} fresh weight)			Chlorophyll b (mg g^{-1} fresh weight)			Total Chlorophyll (mg g^{-1} fresh weight)		
Distance From effluent pit	Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance	Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance	Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance
0-21m (D_1)	0.96	0.80	0.88	0.52	0.59	0.56	1.55	1.52	1.54
21-42m (D_2)	1.01	0.88	0.95	0.62	0.69	0.66	1.58	1.49	1.54
42-63m (D_3)	1.03	0.93	0.98	0.72	0.81	0.77	1.73	1.69	1.71
Beyond 63m (D_c)	1.09	1.11	1.10	0.85	0.99	0.92	1.94	1.83	1.88
Mean Season	1.02	0.93		0.68	0.77		1.70	1.63	

Factors	C.D.	SE(d)	SE (m)	C.D.	SE(d)	SE (m)	C.D.	SE (d)	SE (m)	Significance
Distance (D)	0.02	0.01	0.01	0.01	0.01	0.004	0.03	0.02	0.01	S
Flushing Season (S)	0.02	0.01	0.01	0.01	0.00	0.003	0.02	0.01	0.01	S
Distance × Flushing season (D×S)	0.03	0.02	0.01	0.02	0.009	0.006	0.05	0.02	0.02	S

S:- Significant

3.1.2 Plant growth parameters

3.1.2.1 Plucking point density

The mean value of plucking point density at different distances of the tea plots showed significant variation over control. Table 5 shows the highest plucking point density (71.17 Numbers/50 × 50 cm2) in the control plot i.e. beyond 63m distance from the pit, whereas the lowest value was registered at the nearest plot of tea plots i.e. 0-21m distance from the pit. The trend of decrease of plucking point density (Fig. 3) shows that the tea plot nearest to the pit had the greatest decrease to the extent -13.83% afterwards, however the decrease fallen and registered the lowest decrease to -6.80% over control.

The oil effluent affected tea plantation showed significant ($p \leq 0.05$) seasonal variation in plucking point density the rain flush being registered the higher plucking point density (75.75 numbers/ 50×50 cm^2) and the autumn flush was found to record the lower plucking point density (56.25 numbers/ 50×50 cm^2).

The plucking point density was observed to be decreased near oil field effluent site i.e. 61.33 numbers/per 50×50 cm^2 area. Due to addition of the crude oil the soil physico-chemical properties get affected by creating a water repelling environment around the roots thereby making the soil nutrients unavailable for absorption and because of which the growth of the plants get reduced. The normal plant water relationship of the roots within the soil gets disrupted and it negatively affects the growth of the plant. The shoot length of *Cyperus brevifolius* decreased along with the increase in concentration gradient (29).

3.1.2.2 Number of primaries

Data generated on number of primaries of the oil affected tea plantation are shown in the Table 5. Number of primaries showed significant variation in tea plantation stood at different distances from the effluent pit. Table 5 shows the highest number of primaries (36.50) in the control plot i.e., beyond 63m distance from the effluent pit and the lowest number of primaries (29.50) was recorded at the nearest plot of tea plants i.e., 0-21m distance from the effluent pit. The decreased number of primaries over control influenced by distance gradually decreases along with the distance away from the effluent pit. Significant reduction in plant height was observed in oil-treated soils relative to the control (30). Petroleum oil spillage on soil generally retards plant growth and soil productivity (31), reduces aeration by blocking air spaces between soil particles, and hence creates a condition of aerobiosis and causes root stress in plants which subsequently reduces leaf growth (32). Crude oil spillage reduced soil moisture availability or holding capacity, or increased moisture deficit in agricultural soils, damaging plant growth and yield (33,34)

Fig. 4 shows the trend of decreased number of primaries over control at different level of distances from the pit recording the highest decrease in number of primaries in the plot nearest to the pit and the lowest decrease in number of primaries in the farthest plot. Number of primaries did not differ significantly during two flushes of tea due to oil effluent in the tea plantation.

Table 5: Influence of oil effluent during different flushing season on plucking point density (numbers/50×50 cm^2) and number of primaries of tea leaf.

Flushing season	Pucking point density (number/50×50 cm^2)				Number of primaries per plant			
Distance	Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance		Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance	
0-21m (D_1)	70.00	52.67	61.33		30.00	29.00	29.50	
21-42m(D_2)	75.00	55.33	65.17		32.00	29.67	30.83	
42-63m(D_3)	75.67	57.00	66.33		34.33	32.00	33.17	
Beyond 63m (D_c)	82.33	60.00	71.17		37.67	35.33	36.50	
Mean Season	75.75	56.25			33.50	31.50		
Factors	C.D.	SE(d)	SE (m)	Significance	C.D.	SE(d)	SE (m)	Significance
Distance (D)	2.88	1.33	0.94	S	5.13	2.369	1.675	S
Flushing Season (S)	2.04	0.94	0.67	S	N/A	1.675	1.184	NS
Distance × Flushing season (D×S)	N/A	1.88	1.33	NS	N/A	3.35	2.369	NS

*N/A:- Not Applicable, NS:- Non-significant, S:- Significant

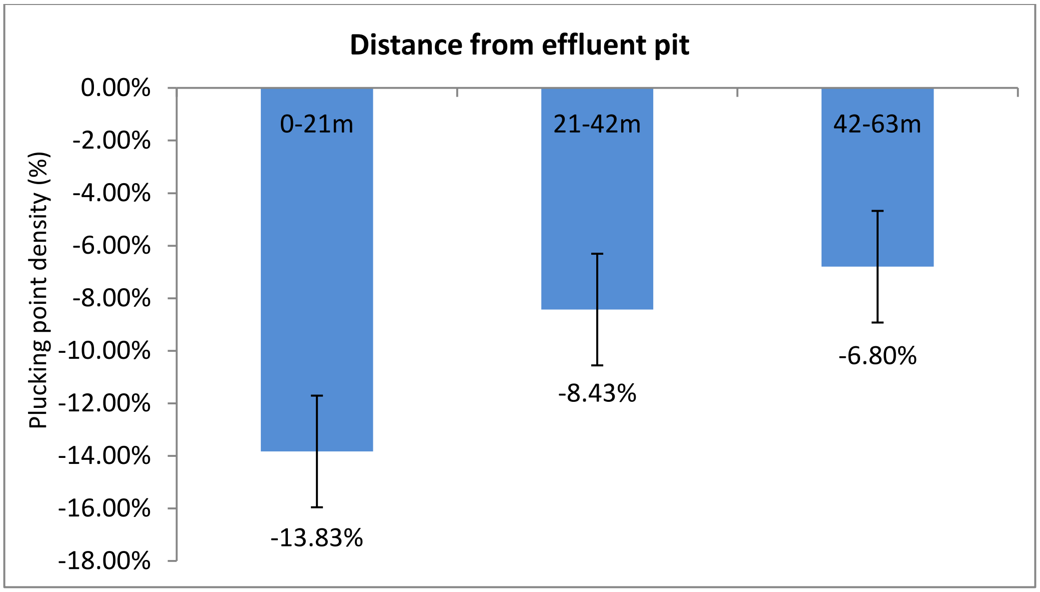

Fig 3: Graphical representation of percentage decrease plucking point density over control influenced by distance from the effluent pit

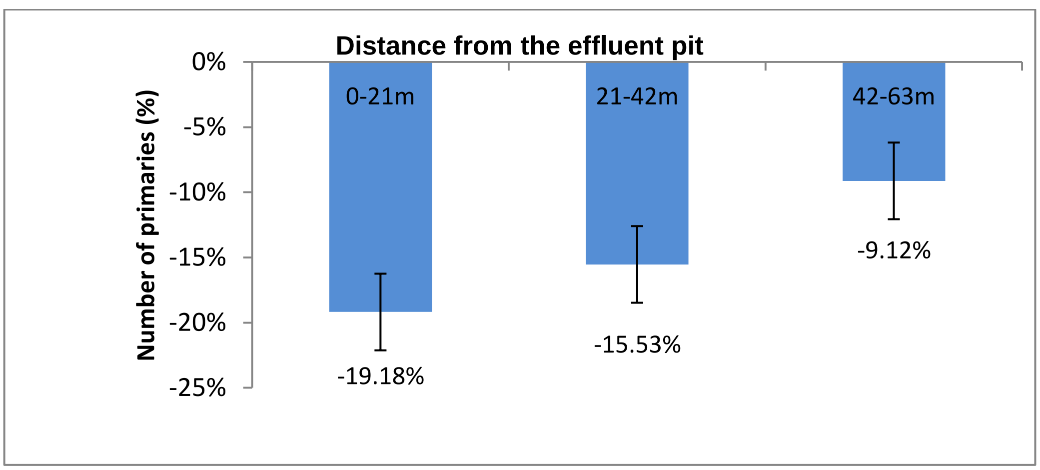

Fig 4: Graphical representation of decreased number of primaries over control influenced by distance from the effluent pit

3.2 Soil Sample

<u>3.2.1. Physical properties of soil</u>

3.2.1.1 Bulk density

Bulk density is defined as the mass of many particles of the material divided by the total volume they occupy, while porosity is the measure of the void spaces in a material. The porosity was negatively and significantly correlated with bulk density from Table 6. The present study revealed that the bulk density of tea grown soil seems to be in a higher range up to a distance of 21m distance from the effluent pit i.e., 1.31 Mg cm^{-3} as compared to the control i.e., 1.21 Mg cm^{-3}. The viscous crude oil probably settled into the pores to increase both the soils wet weight and the liquid content which in turn might have increased the Bulk density. Presence of hydrocarbon resulted in compactness of the soil particles and increases in bulk density of soils (35,36). Fig 5 shows an increase in bulk density over control from 8.26% at 0-21m distance to 9.09% at 21-42m distance yet it dropped suitably to 4.96% increase in soil of the tea plot at 42-63m distance indicating initiation of comfort level in respect of bulk density.

3.2.1.2 Porosity

The porosity of tea grown soil get reduced near the effluent pit (44.99-45.64% porosity) and it get increases at the distances away from the effluent pit i.e., (49.79% porosity) (Table 6). Even the tea plot at 42-63m distance recorded significantly lower value (47.12% porosity) over control. The oil effluent was found to have significant effect on the tea flush with the autumn flush being recorded the higher value (46.91% porosity) and the rain flush registered the lower value (46.87% porosity). Due to the blockage of pore spaces by crude oil the porosity percentage get reduced near the spillage point. These findings are in agreement with Percentage of porosity in the crude oil spilled areas got reduced as compared to the control site in Lakwa and Rudrasagar oilfields of Assam (35,37,38). Fig. 6 shows the trend of decrease of porosity at different level of distance over control. Decrease in porosity within 0-21m distance was found to -4.15% afterward it rose to -4.80% at 21-42m distance but then fell to -2.67% at 42-63m distance.

3.2.1.3 Hydraulic conductivity

Hydraulic conductivity is a physical property which measures the ability of the material to transmit fluid through pore spaces and fractures in the presence of an applied hydraulic gradient. The oil effluent was found to affect significantly hydraulic conductivity of soil at different level of distances with the tea plot at 0-21m distance registering the lowest value (0.25 cm/min) and the control tea plot beyond 63m distance the highest value (0.35 cm/min). Each level of distance differed significantly in respect of hydraulic conductivity with rise of the value corresponding to higher level of distances. (Table 6). Due to the blockage of the soil pores the obstruction of water movement get increased due to which the hydraulic conductivity in the spilled area get reduced. The hydraulic conductivity gets reduced in the crude oil polluted soil as compared to the control (36,39). Fig. 7 presents the trend of percentage decrease in the value of hydraulic conductivity with respect to distances of the tea plot from the effluent collecting pit. There is gradual decrease in the value of percentage decrease of hydraulic conductivity from the tea plot nearest to the pit to the tea plot farthest from the pit over control. Hydraulic conductivity decreased to the maximum of -28.57% in the nearest tea plot (0-21m distance) and it decreased to the minimum of -5.71% in the farthest tea plot (42-63m distance).

3.2.1.4 Soil Particle analysis

Soil particle analysis refers to the proportion of sand, silt and clay sized particles that make up the mineral fraction of the soil. The soil particle analysis on the hand did not have any significant variation with respect to distance and season (Table 7). Thus, it is observed that the presence or absence of crude oil failed to affect the soil texture. According The soil texture being an inherent property of soil, the presence or absence of crude oil had no influence on soil texture (35,40, 41).

Table 6: Influence of oil effluent on soil bulk density (Mg m^{-3}), porosity (%) and Hydraulic conductivity (cm min^{-1}) of tea grown soil during different flushing season

Flushing Season	Bulk Density (Mg m^{-3})				Porosity (%)				Hydraulic conductivity (cm min^{-1})			
Distance	Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance		Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance		Rain Flush (S_1)	Autumn Flush (S_2)		Mean Distance
0-21m (D_1)	1.32	1.3	1.31		45.42	45.86	45.64		0.25	0.26		0.25
21-42m(D_2)	1.33	1.31	1.32		44.58	45.42	44.99		0.31	0.31		0.31
42-63m(D_3)	1.28	1.25	1.27		47.07	47.17	47.12		0.32	0.33		0.33
Beyond 63m (D_c)	1.19	1.23	1.21		50.40	49.17	49.79		0.36	0.34		0.35
Mean Season	1.28	1.27			46.87	46.91			0.31	0.31		
Factors	C.D.	SE(d)	SE (m)	Significance	C.D.	SE(d)	SE (m)	Significance	C.D.	SE(d)	SE (m)	Significance
Distance (D)	0.02	0.01	0.01	S	0.82	0.38	0.27	S	0.02	0.01	0.01	S
Flushing Season (S)	N/A	0.01	0.01	NS	0.58	0.27	0.19	S	N/A	0.01	0.01	NS
Distance × Flushing season (D×S)	0.03	0.02	0.01	S	N/A	0.53	0.38	NS	N/A	0.01	0.01	NS

*N/A:- Not Applicable, NS:- Non-significant, S:- Significant

Table 7: Impact of oil effluent during different flushing season on soil particle analysis (%)

Flush	Sand				Silt				Clay			
Distance from the effluent pit	Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance		Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance		Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance	
0-21m (D_1)	74.23	74.28	74.25		3.22	3.25	3.23		22.55	22.47	22.51	
21-42m(D_2)	74.31	74.29	74.29		3.25	3.27	3.26		22.44	22.43	22.43	
42-63m(D_3)	74.32	74.31	74.31		3.33	3.29	3.31		22.38	22.41	22.39	
Beyond 63m (D_c)	74.60	74.70	74.65		2.60	3.20	2.90		22.90	22.10	22.50	
Mean Season	74.36	74.39			3.10	3.25			22.56	22.35		
Factors	C.D.	SE(d)	SE (m)	Significance	C.D.	SE(d)	SE (m)	Significance	C.D.	SE(d)	SE (m)	Significance
Distance (D)	N/A	0.33	0.24	NS	N/A	0.33	0.23	NS	N/A	0.35	0.25	NS
Flushing Season (S)	N/A	0.24	0.17	NS	N/A	0.23	0.16	NS	N/A	0.25	0.18	NS
Distance × Flushing season (D×S)	N/A	0.47	0.33	NS	N/A	0.46	0.33	NS	N/A	0.50	0.35	NS

*N/A:- Not Applicable, NS:- Non-significant, S:- Significant

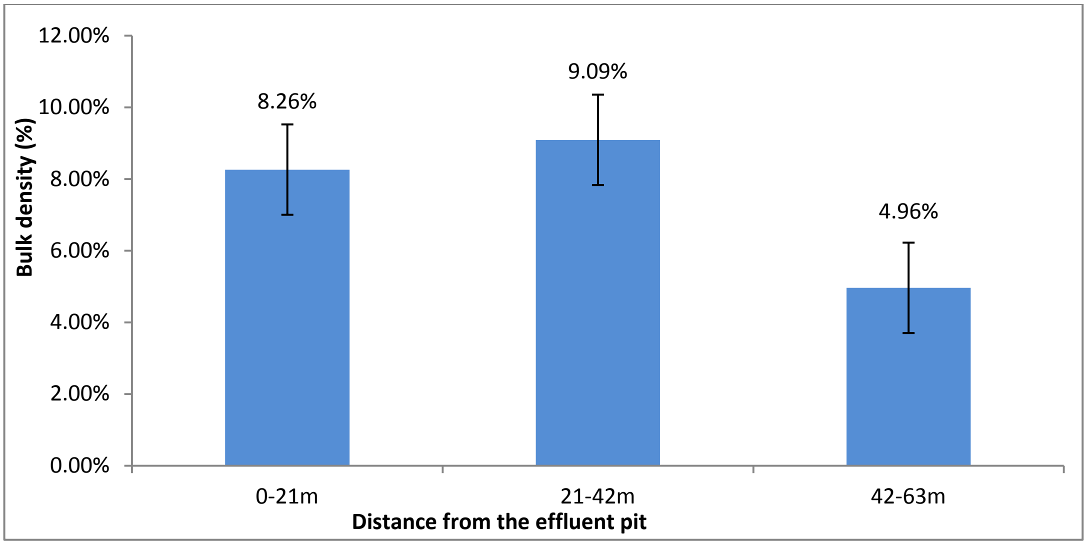

Fig 5: Graphical representation of percentage increase in bulk density (%) over control as influenced by distance from effluent pit

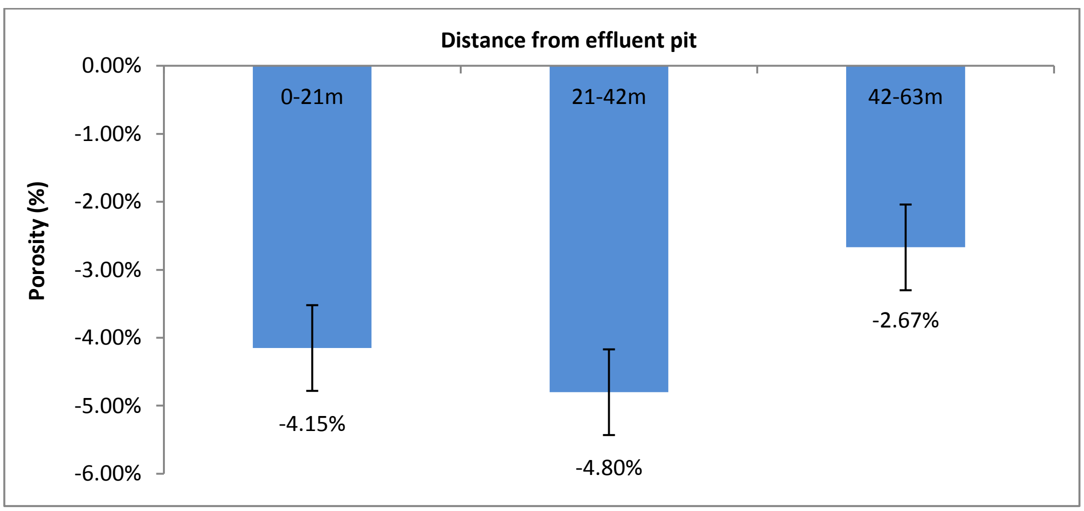

Fig 6: Graphical representation of percentage decrease of porosity (%) over control as influenced by distance

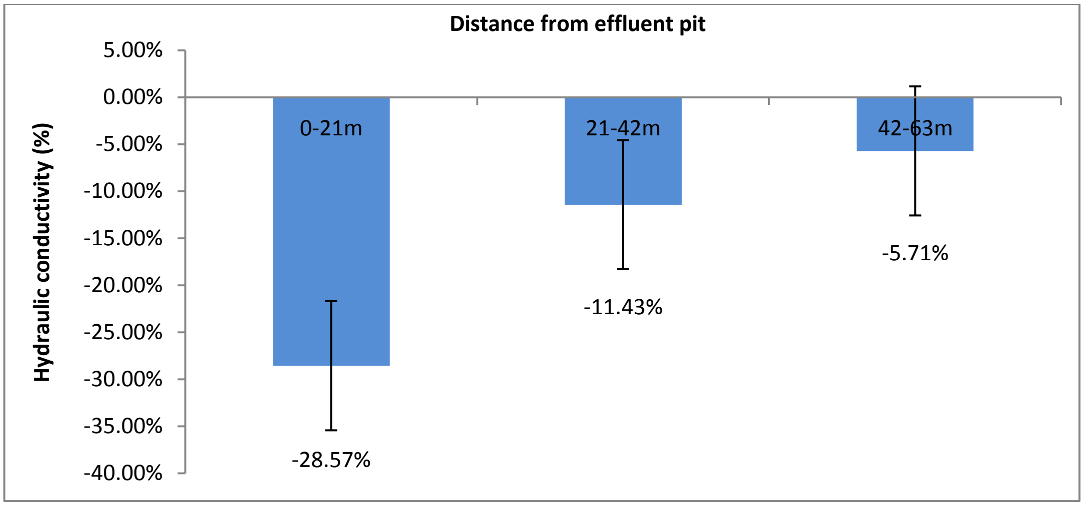

Fig 7: Graphical representation of percentage decrease of hydraulic conductivity (%) over control influenced by distance from effluent pit

3.2.2 Chemical properties of soil

3.2.2.1 Ph

Determination of pH is actually a measurement of hydrogen ions activity in soil-water system. The pH value gives an idea about the availability of nutrient to plants. In the present study, the soil pH increased near the effluent pit and was found to get reduced in the distance away from the pit from table 8 and fig. 8. It may perhaps be due to the bacterial biodegradation of crude oil under the anaerobic conditions present in the soil macro and micro-pores. Increase in soil pH by 26% in crude oil polluted soil than the unpolluted soil (36, 42).

3.2.2.2 Total organic carbon

Total organic carbon content is defined as the amount of carbon found in an organic compound. The study revealed that the organic carbon was found to be increased near the effluent pit i.e. 13.03g/kg and it got reduced to 12.67 g/kg in the distance beyond 63 cm from the effluent pit (Table 8). Fig. 9 shows the trend of increase or decrease in the values of organic carbon over control at different distances from the pit. The tea plot nearest to the pit and farthest from the control plot registered a minimal increase in the value of organic carbon (2.84%), however, the tea plot (42-63m distance) nearest to the control recorded the higher value of decrease (-12.55%) than the tea plot (21-42m distance) preceding next to it (-5.99%).

The increase of organic carbon may be attributable to the carbon from the discharged crude oil. Increase of organic carbon content is directly proportional to the increase of crude oil addition to the soil. (37, 43).

3.2.2.3 Electrical conductivity

The present study revealed that electrical conductivity increased near the effluent site i.e., 0.33 dS/m (Table 8) and it gradually decreased in the distances away from the effluent site. Fig. 8.3 shows the trend of increase in electrical conductivity over control at different level of distances from the pit. It can be seen that the two plots nearer to the pit registered the same percentage increase of 13.79% and the tea plot farthest from the pit recorded only 6.89% increase in electrical conductivity. As the crude oil consists of petroleum hydrocarbons which possess huge counts of ions and could bond with the existing ions in the soil, therefore, electrical conductivity of the contaminated soil increased due to crude oil contamination. Electrical conductivity got increased along with crude oil contamination (46).

3.2.2.4 Available Nitrogen, Phosphorous & Potassium

The availability of Nitrogen seemed to get increased up to a distance of 63m from the effluent pit and it decreased at the distance beyond 63 m from the effluent pit (Table 9). It might be due to fixation of atmospheric Nitrogen by the microorganisms which assimilates the hydrocarbon. Increase of pH in the oil spill may contribute to the higher Nitrogen value (44). Total nitrogen in the crude oil contaminated soil were found to be almost double than their adjacent unpolluted areas (36,37,45). On the other hand the available Phosphorous have not shown any variation with respect to distance and season. The available phosphorous showed a significant reduction in the crude oil affected area (36). It might be due to leakage of saline effluent along with crude oil; ionic concentration may build up resulting in more potassium in crude oil contaminated soil. Exchangeable potassium was found to be slightly higher in the crude oil affected areas than the unaffected areas (17,37)

Table 8: Influence of oil effluent on soil pH, organic carbon (g kg^{-1}) and electrical conductivity (dS m^{-1}) of tea grown soil during different flushing seasons in Shalmari area

Flush	Soil pH			Total Organic carbon (g kg^{-1})			Electrical conductivity (dS m^{-1})		
Distance from the effluent pit	Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance	Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance	Rain Flush (S_1)	Autumn Flush (S_2)	Mean Distance
0-21m (D_1)	5.96	5.92	5.94	13.06	13.00	13.03	0.32	0.34	0.33
21-42m(D_2)	5.68	5.62	5.65	11.80	12.01	11.91	0.33	0.33	0.33
42-63m(D_3)	5.85	5.84	5.85	11.00	11.17	11.08	0.30	0.32	0.31
Beyond 63m (D_c)	5.77	5.76	5.76	12.70	12.63	12.67	0.28	0.29	0.29

Mean Season	5.82	5.78			12.14	12.20			0.31	0.32		
Factors	C.D.	SE(d)	SE (m)	Significance	C.D.	SE(d)	SE (m)	Significance	C.D.	SE(d)	SE (m)	Significance
Distance (D)	0.08	0.04	0.02	S	0.15	0.07	0.05	S	0.02	0.01	0.01	S
Flushing Season (S)	N/A	0.02	0.02	NS	N/A	0.05	0.04	NS	N/A	0.01	0.01	NS
Distance × Flushing season (D×S)	N/A	0.05	0.04	NS	N/A	0.09	0.07	N	N/A	0.01	0.01	NS

*N/A:- Not Applicable, NS:- Non-significant, S:- Significant

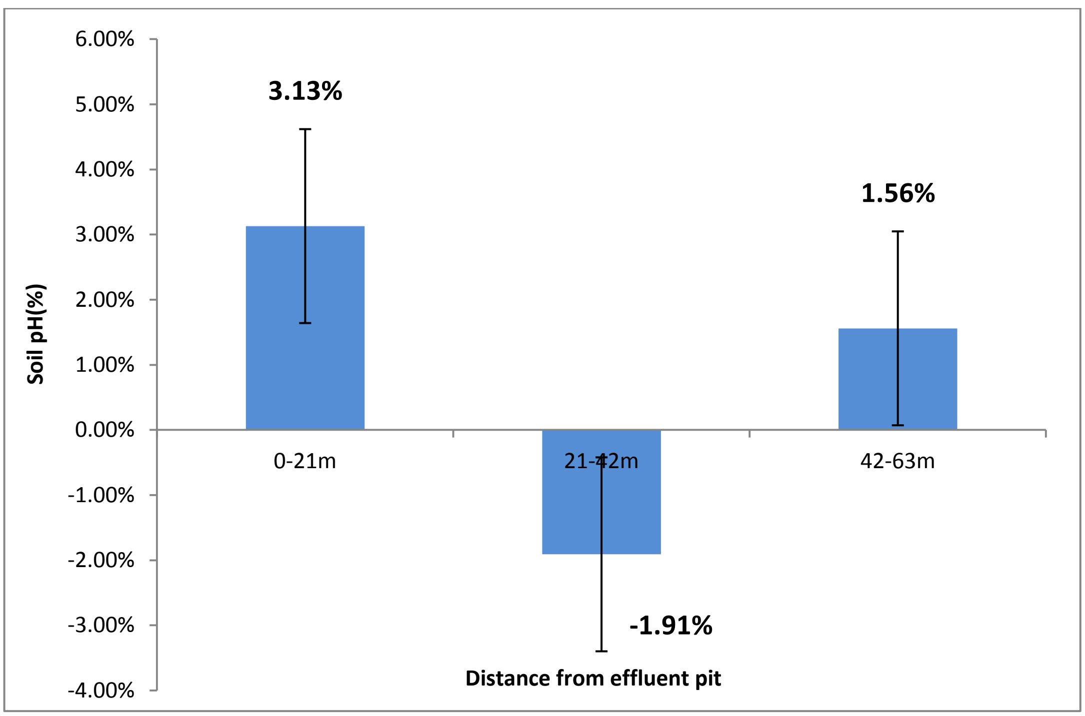

Fig 8: Graphical representation of decreased or increased soil pH (%) over control influenced by distance from the effluent pit

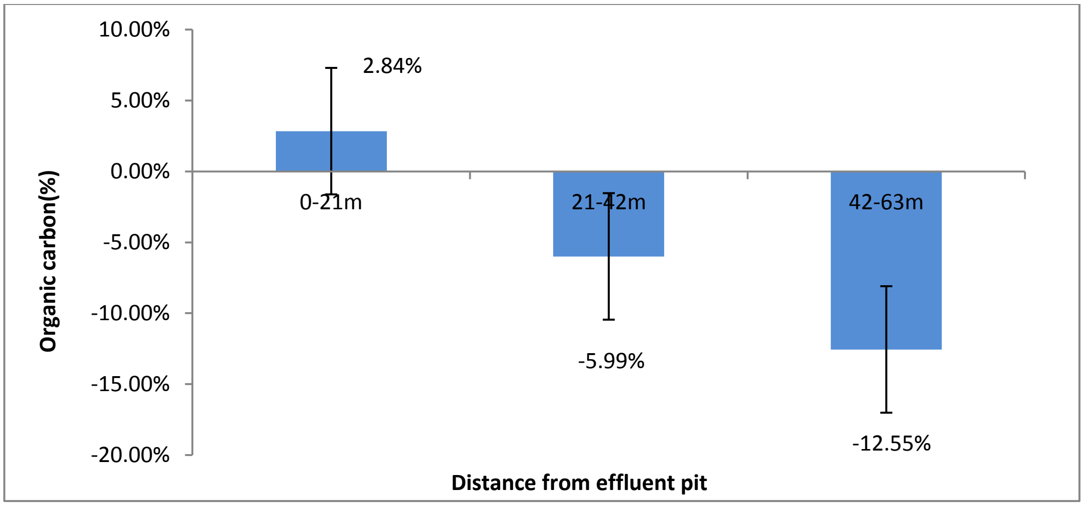

Fig. 9: Graphical representation of percentage increase/decrease organic carbon (%) over control influenced by distance from effluent pit

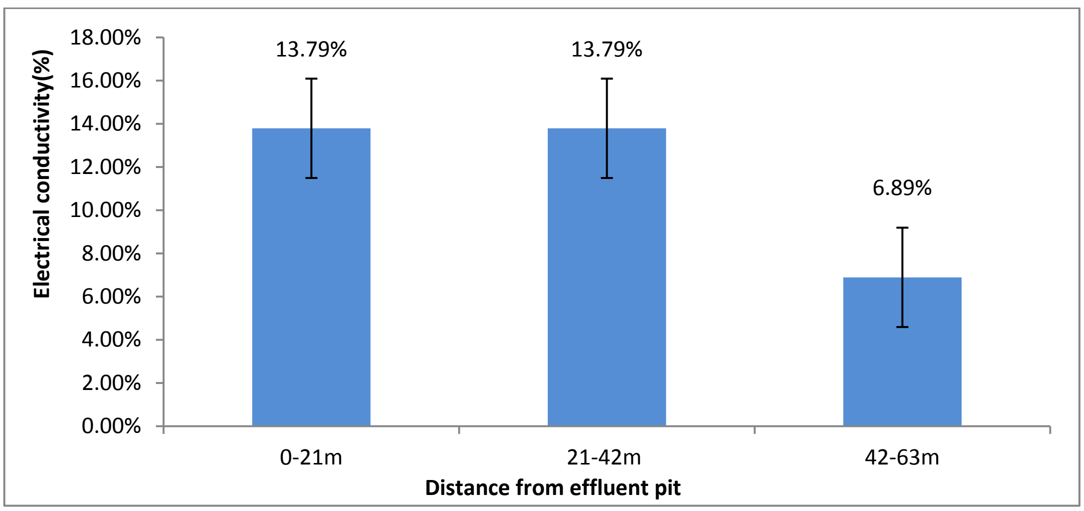

Fig. 10: Graphical representation of percentage increase of electrical conductivity (%) over control influenced by distance from effluent pit

Table 9: Effect of oil effluent on available nitrogen (kg ha^{-1}), available phosphorous (kg ha^{-1}) and available potassium (kg ha^{-1}) of tea grown soil during different flushing seasons

Flushing season	Available Nitrogen (kg ha^{-1})			Available Phosphorous (kg ha^{-1})			Available Potassium (kg ha^{-1})		
Distance	Rain Flush	Autumn Flush	Mean Distance	Rain Flush	Autumn Flush	Mean Distance	Rain Flush (S_1)	Autumn Flush	Mean Distance

	(S_1)	(S_2)		(S_1)	(S_2)			(S_2)	
0-21m (D_1)	768.30	765.20	766.80	39.553	39.6	39.577	240.00	243.00	241.50
21-42m(D_2)	771.50	770.20	770.90	40.66	40.563	40.612	239.00	234.67	236.83
42-63m(D_3)	777.30	775.20	776.30	42.553	41.567	42.06	220.00	210.00	215.00
Beyond 63m (D_c)	681.10	681.30	681.20	35.67	35.72	35.695	214.56	215.11	214.84
Mean Season	749.60	747.90		39.609	39.363		228.39	225.69	

Factors	C.D.	SE(d)	SE (m)	Significance	C.D.	SE(d)	SE (m)	Significance	C.D.	SE(d)	SE (m)	Significance
Distance (D)	2.07	0.96	0.68	S	N/A	2.154	1.523	NS	8.45	3.90	2.76	S
Flushing Season (S)	N/A	0.68	0.48	NS	N/A	1.523	1.077	NS	N/A	2.76	1.95	NS
Distance × Flushing season(D×S)	N/A	1.35	0.96	NS	N/A	3.046	2.154	NS	N/A	5.52	3.9	NS

*N/A:- Not Applicable, NS:- Non-significant, S:- Significant

4. CONCLUSION

The present findings show that the nearest area to the effluent pit found to be the most vulnerable. This study necessitates the requirement of remediation in the affected tea plantation due to seepage of oil field effluent from the collecting pit upto a distance of 63m. Some of the technologies for remediation of the soil are phytoremediation, bioremediation such as *Boehmeria nivea* (L.) Gaudich, *Pteris vittata* (L.), *Pteris cretica* (L.) could be proposed as promising materials for heavy metal and PAHs combined pollution remediationfor phytoremediation and for bioremediation living organisms like microbes and bacteria are used like *Pseudomonas aeroginosa strains* AS 03 & NA 108; and chemical degreaser/detergent emulsions such as Trichloroethylene and Perchloroethylene.

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