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PHYSICO-CHEMICAL PROPERTIES OF SOIL AND QUANTITATIVE ANALYSIS OF A HERBACEOUS COMMUNITY AFTER BLOWOUT OF AN OIL WELL

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ABSTRACT

The effects of pollution by crude petroleum on the soil physico-chemical properties like colour, moisture content, porosity, water holding capacity, pH, total nitrogen, organic carbon, phosphorus, potassium, C/N and C/P ratios, crude oil content and the periodical effects on some ecological parameters have been investigated after eight years of accidental blowout of an oil well in upper Assam, India. Crude oil pollution has a significant impact on soil environment. The total number of species decreases with increasing oil level in the different sites. Annuals are more affected than the perennials; the effect being more severe in the dry period. The highest similarity index (SI) (0.724) was found between site B (moderately polluted site) and C (less polluted site). Species diversity index (SDI) decreases with the increasing oil level while index of dominance (CD) showed an increasing trend with the increasing pollution level. *Eleocharis palustris*, a perennial monocot, is the highest percentage contributor of total community IVI. The dual mode of propagation and well-developed underground system of the perennials help it to be oil tolerant or oil resistant.

INTRODUCTION

Accidental blowout of oil well occurs mainly due to high subsurface or formation pressure. Blowout of oil well not only increases large scale devastation, ecological and financial loss but also leaves behind many long term as well short term effects. Since blowout is associated with the burning of out coming volatile natural gas along with massive oil spill, it generally wipe out the standing flora and fauna. Vegetation recovery in the subsequent period is quite important from the ecological point of view and such dominant oil resistant species can provide the basic information necessary for further detailed ecological study. In this paper an attempt has been made to evaluate the soil physico-chemical properties of oil contaminated area as well as to sort out the oil resistant species by quantitatively analysing the differentially crude oil polluted sites following an accidental blowout of an oil well at upper Assam.

STUDY SITES AND CLIMATE

The study was conducted after 8 years of the accidental blowout of an oil well at Dikom, which is situated at the midst of Dikom Tea Estate and is about 20 km from Dibrugarh, Assam, India. The area receives moderate to high rainfall, high relative humidity round the year and the temperature variation between 5° to 36°C. Dry period is considered from November to February and rainy wet period from March to October.

MATERIALS AND METHODS

The study area is demarcated as site A (highly polluted areas with a radius of 10 meter from the oil well where the oil layer is 1-2 cm), site B (moderately polluted area with a radius of 15 meter from the oil well where oil layer is 0.5-1 cm) and the site C (less polluted area with a radius of 20 meter from the oil well where oil layer is less than 0.5 cm).

Analysis of Soil Physico-Chemical Properties

Soil samples were collected from each site of the study area at a depth of 0-10 cm using soil auger. A total of 15 samples, 5 from each sites, were taken randomly and brought in polythene bags to the laboratory. The collected soil samples were then prepared for analysis.

The colour was determined on tentative basis by visual observations of different soil samples. Soil moisture content, porosity and water holding capacity were determined according to the method of Ambasht (1986). Soil pH was determined in 1:5 soil solutions for fresh soil using a double electrode pH meter (Digital pH meter 335, Systronic Co. Ltd.), total nitrogen by modified Kjeldahl (indophenol) method (Scheiner 1976), total organic carbon by rapid titration method (Walkley & Black 1934), phosphorus by (Jackson 1958) and potassium by flame photometry (Black 1965). Crude oil content was determined by solvent extraction method using petroleum ether.

Quantities Analysis of Vegetation

The number of sampling unit ($1m^2$) varied according to vegetation pattern and area. A total of 10, 25 and 50 sampling units were studied in the site A , B and C respectively and species encountered therein were recorded at monthly intervals of time. The Importance Value Index (IVI) which is an integrated measure of the relative frequency (RF), relative density (RD) and relative dominance (RDo) was calculated for each species as per the method of Curtis (1959) and Misra (1968).

The species diversity index (SDI) was determined by Shannon & Weaver (1949).

$$\overline{H} = \sum_{i=1}^{s} (N_i/N) \log_2 (N_i/N)$$

Where, N_i = Total number of individual of species i.

N = Total number of individuals of all species in the area.

The Index of dominance (ID) values were measured by Simpson index (Simpson 1949) as:

$$ID = \sum_{i=1}^{s} (N_i/N)^2$$

Where, Ni and N were the same as for Shannon-Weaver information equation.

Similarity index (SI) was calculated according to Sorensen (1948) as given below.

$$SI = \frac{2C}{A + B}$$

Where, A and B are number of species in stand A and B respectively and C is the number of species common to both stands.

RESULTS AND DISCUSSION

The results of physico-chemical properties of soil samples are summarized in Table 1. The colour of the soil is found to be black in all the three crude oil polluted sites as a result of deposition of crude oil in the soil. The soil moisture content was found to be less in highly polluted site (26.58%) than the less polluted site (40.62%). Likewise, porosity and water holding capacity, 29.68% and 30.98% respectively, were found to be less in the highly polluted site as against high porosity and WHC (42.02%) and (40.03%) respectively in the less polluted site. Soil moisture measurement indicates that the soil was drier in all the three crude oil polluted sites and particularly more in the highly polluted site (Site A) than the less polluted site (Site C). It is evident from the results that the oil which penetrates the soil layer prevents both upward and downward movements of water. Wein & Bliss (1973) advocated that crude oil affected soil surface was drier than lower part of the contaminated soil profile. Present investigation also indicates that water-holding capacity of crude oil contaminated soil was directly proportional to porosity because WHC in the highly polluted site (site A) is found to be less than less polluted site (site C). The formation of thick crude oil coating above the soil surface might have resulted in compactness of soil particles and reduced, both porosity and WHC, which is in the order of highly polluted site (site A) > moderately polluted site (site B) > less polluted site (site C). Low soil moisture content in the crude oil contaminated soil could be due to reduced soil moisture recharge caused by hydrophobic nature of the polluted soil. This is in agreement with the earlier findings of Rowell (1977) and De Jong (1980).

In the three crude oil polluted sites, the soils are acidic in nature. Usually microbial utilization of hydrocarbon leads to the formation of organic acids (Alexander 1977). Thus, the acids probably produced by the microorganisms implicated for the reduction in pH level in all the three polluted sites (Nwachukwa & Ugoji 1995).

The present investigation also shows that total nitrogen, organic carbon and potassium were present in order of highly polluted site (Site A) > moderately polluted site (Site B) > less polluted site (Site C). The increase in total nitrogen in highly polluted site than the less polluted site is due to fixation of more available nitrogen by microorganisms, which assimilated more hydrocarbons as suggested by Schwendenger (1968). Udo & Faymei (1975) and Rao (1992) also reported that available nitrogen increases with increased contamination of oil in soil. The increase in organic carbon with increase in pollution levels was attributable to carbon from crude oil. Udo & Faymei (1975) also advocated that increase in organic carbon is directly proportional to increase of crude oil level in the soil. The high C/N ratio in highly polluted site (Site A) leads to immobilization of soil nitrates

Table: 1. Physico-chemical properties of soil in the study area.

Parameters	Highly polluted site (Site A)	Moderately polluted site (Site B)	Less polluted site (Site C)
Colour	Black	Black	Black
Soil moisture (%)	26.58 ± 0.37	30.20 ± 1.26	40.62 ± 1.66
Porosity (%)	29.68 ±1.18	31.02 ± 2.60	45.02 ±3.15
WHC (%)	20.98 ±2.36	23.04 ± 1.83	40.03 ± 2.15
pH	3.54 ± 0.17	5.40 ± 0.30	5.80 ± 0.11
Total nitrogen (%)	0.14 ± 0.002	0.13 ±0.001	0.12 ± 0.002
Organic carbon (%)	13.36 ± 1.65	11.41 ± 1.27	9.48 ±1.47
Phosphorus (ppm)	3.84 ± 0.41	4.20 ± 0.46	4.20 ± 0.50
Potassium (ppm)	88.92 ± 1.38	73.41 ± 1.18	67.32 ± 1.43
Carbon/Nitrogen	165.60	87.77	79.00
Carbon/Phosphorous	3.43	2.72	2.26
Crude oil content (ppm)	5344	1011	Trace

Data are collected from 5 samples and express as Mean ± Standard deviation.

coupled with reducing environment brought about by the crude oil pollution, which is accounted for low level of NO_3-N in oil contaminated soil. The reduction in extractable phosphorus with increased contamination of soil in the present study may probably be due to high C/P ratio. Exchangeable ion potassium (K^+) was found to be high in highly polluted site. It may be attributed to leakage of saline effluent along with crude oil; ionic concentration may buildup resulting in more K^+ in highly polluted areas than the less polluted areas. Concentration of crude oil was found to be 5344 ppm and 1011 ppm in highly polluted site (Site A) and moderately polluted site (Site B) respectively as against trace amounts in the less polluted site (Site C). Results indicate that blowout of crude oil may contaminate the soil more in the nearby blowout source, as a result of which concentration of crude oil was found to be higher in the nearby region of the blowout source.

It is observed from the results that physico-chemical properties of soil samples, collected from different distances of oil blowout source, have a significant impact on soil environment up to a distance of 20 m radius from the source following an accidental blowout of an oil well.

The results of the periodical effects of crude oil pollution on species number is given in Table 2. The data indicate that total number of species decreases with the increasing oil level. The effect being more severe in dry period where the highest percentage reduction (16.67%) occurs in the highly polluted site (Site A). Annuals are mostly affected than perennials. The species present in the Sites B and C have either very low frequency or totally absent in the most polluted site (Site A) are most sensitive to crude oil. Only a few species participated in the community formation as dominant or co-dominants at Site A, nearest to the blowout source (1-2 cm oil layer). This indicates significant change in the ambient atmosphere and edaphic characters at the high oil coated site. It has been suggested that variation in environmental factors affects the adaptive abilities of microorganisms, with the result that only those species which have already adapted to these conditions, or those which can acclimatize to new condition, may participate in the community formation (McMohan 1980, Bradshaw 1983). The species susceptible to crude oil stress are removed and others, which are more tolerant, become prevalent (Baruah & Sarma 1996). Under oil films, leaves of herbs may remain green initially but eventually turn yellow and die. Plants, however, recover by producing new shoot mainly from vegetative propagules of perennial herbs, but seedlings and annuals rarely recover directly. In long term, however, recovery from crude oil spillage has been observed many times (Buck & Harrison 1967, Ranwall 1968, Stebbings 1968, Smith 1968, Cowell 1969). The evidence from our observation of the accidental contamination of crude oil is that perennial grasses and sedges recover well from oil spillages and help these species to establish themselves as oil tolerant or oil

Table 2: Periodical effects of crude oil pollution on species numbers.

Parameters	Study sites	Oil layer (cm)	Dry period	Wet period	% reduction in species numbers during dry period
Total number of species	A	1-2	10	12	16.67
	B	0.5-1	38	42	9.52
	C	0.5	67	74	9.46
Total numbers of annuals (Al) and perennials (Pl)	A	1-2	04(Al),6(Pl)	05(Al),7(Pl)	20(Al), 14.28(Pl)
	B	0.5-1	32(Al),6(Pl)	35(Al),7(Pl)	8.57(Al), 14.28(Pl)
	C	0.5	61(Al),6(Pl)	67(Al),7(Pl)	8.89(Al), 14.28(Pl)

Dry period: November to February. Wet period: March to October.

adapting species by remaining dormant in unfavourable dry period and resuming their activity in the subsequent rainy period by sprouting out new tillers vegetatively. The above results are in agreement with the earlier findings of Baker (1971), Buck (1977), Kinako (1981) and Baruah & Sarma (1996). Cowell & Baker (1967) reported that badly oiled marshes at Bentlass on Pembroke River were severely damaged after the Chrysie P. Golundris oil tanker accident in 1967 have completely recovered two years later. In our observations, it was noticed that almost all herbaceous species in the study area could grow with their roots in oil mat and oily soil and all the living roots grew vertically downwards and side branches were absent. Below the oil layer adventitious roots were found. Stebbings (1968) also got similar findings. In reviewing the available literature, Baker (1970) concluded that oil in the soil might harm plants, benefit them, or not noticeably affect them, depending on the circumstances. So crude oil modify the response of vegetation either by acting synergistically or antagonistically.

The analysis of herbaceous community by different indices like Similarity Index (SI), Species Diversity Index ($\bar{H}$) and Index of Dominance (ID) is given in the Table 3. The highest similarity index (0.724) was found between site B and site C in the rainy period and the lowest similarity index (0.259) between the side C and site A in the dry period. Since site B is the moderately polluted, it contains the species of both site A and site C, hence its similarity index is highest. Again, the site A and site C differs according to their oil content and species content or in other words their similarity index is less where the resistant species survive in site A and many of the species of site C perishes due to the harmful affects of crude oil pollution.

Species diversity index decreases with the increase in oil level. This declining trend in species diversity index with the increasing oil level under the study agree with similar trend observed earlier by Odum (1969) that, most stresses will undoubtedly led to a lowering of diversity. McCleahen (1978) and Narayan et al. (1994) have reported a similar trend in Shannon-Weiner function along a decreasing gradient of pollution load. Species diversity is inversely proportional to pollution load. The stability of community is related to species diversity; the higher the value of species diversity index, the greater will be the stability of community structure. Odum (1971) reported that species diversity index tend to be low in physically controlled ecosystems and high in biologically controlled ecosystems.

As maximum Index of Dominance was recorded at the most polluted site and comparatively lower in the less polluted site (Table 3). It is clear indication of the fact that the site situated close to oil blowout source suffered maximally due to heavy pollution load, and consequently the most sensitive species have disappeared leaving only a few oil resistant species represented by large number of individuals whereas in less polluted site dominance is shared by many species. Species diversity

Table 3: Periodical effect of crude oil pollution on different ecological indices.

Study sites	Oil layer (cm)	Period	Ecological indices		
			Similarity	Diversity	Dominance
Site A	1-2	Dry Period	0.416 (A&B)	0.703	0.298
		Wet Period	0.444 (A&B)	0.721	0.276
Site B	0.5-1	Dry Period	0.723 (B&C)	1.132	0.195
		Wet period	0.724 (B&C)	1.147	0.167
Site C	0.5	Dry Period	0.259 (C&A)	1.813	0.131
		Wet Period	0.279 (C&A)	1.869	0.117

index and index of dominance are inversely related, reflecting that the communities are heterogeneous at distantly situated site because ambient conditions favoured the growth, survival and regeneration of natural vegetation. This is in agreement with the earlier findings of Narayan et al. (1994). Interestingly, the winter period showed lower similarity and diversity values and higher dominance values in the study area. It is obvious from the result that as the number of species are affected by crude oil, the different indices are also affected and this effect is more severe in dry period when the water budget of the plants and soils comes under massive oil induced physiological stress. Baruah & Sarma (1993) have reported that the effect of crude oil on plant is more severe in dry period than rainy wet period.

The periodical percentage IVI (Importance Value Index) contribution to the herbaceous community is given in Table 4. The three species namely *Eleocharis palustris*, *Cyperus brevifolius* and *Cynodon dactylon* are the dominant species in all the three sites. The average percentage IVI contribution to the community shows *Eleocharis palustris* as the highest contributor (24.80 and 27.44 % respectively in dry and wet period) followed by *Cyperus brevifolius* (19.34 and 21.33 % respectively in dry and wet period) and *Cynodon dactylon* (4.68 and 4.71% respectively in dry and wet period). The withdrawal of oil susceptible annuals through death relaxes the evergoing ecological competition and thereby favouring the oil tolerant (or rather escaping) perennial monocots to establish their dominance. This along with the reduction in the number of species (mainly annuals) attributed to the high percentage IVI contribution by perennials in the herbaceous community. Besides unsuccessful germination of the seeds due to the toxic and hydrophobic nature of crude oil, which may prove fatal to the embryo due to unavailability of water and oxygen for germination (Baruah & Das 1994) and failure of seedling establishment of the annuals, also results in an increased dominance of the perennials. The perennials, particularly *Eleocharis palustris*, *Cynodon dactylon* and *Cyperus brevifolius*

Table 4: Percent IVI contribution to the community by three dominant species in dry and wet periods.

Plant species	Study sites	IVI	%IVI contribution to the community	Average of the three sites	Total IVI
	Dry Period (November to February)				
Eleocharis palustris	A	105.61	35.20	27.44	300
	B	71.92	23.97		300
	C	69.43	23.14		300
Cyperus brevifolius	A	68.77	22.92	21.33	300
	B	63.28	21.09		300
	C	59.97	19.99		300
Cynodon dactylon	A	11.83	3.94	4.71	300
	B	13.57	4.52		300
	C	15.98	5.66		300
	Wet Period (March to October)				
Eleocharis palustris	A	89.72	29.91	24.80	300
	B	67.31	22.44		300
	C	66.19	22.06		300
Cyperus brevifolius	A	59.71	19.90	19.34	300
	B	58.33	19.44		300
	C	56.09	18.69		300
Cynodon dactylon	A	12.58	4.19	4.68	300
	B	13.13	4.37		300
	C	16.47	5.49		300

have their dual mode of propagation (vegetative as well as sexual) helps them to establish as oil tolerant or oil adapting species by remaining dormant in the unfavourable dry period and resuming their activity in the subsequent rainy wet period by sprouting out new tillers vegetatively.

Pollution of environment with crude petroleum is a common phenomenon associated with oil industries operating in Assam, India (Baruah & Sarma 1993, 1996). The crude petroleum has adverse effects on soil ecosystem as well as on floristic composition or vegetation cover. Furthermore, crude petroleum contains carcinogenic compounds such as polycyclic aromatic compounds (Sewell 1975), therefore, spillage of such compounds in the environment exposes human beings to carcinogens.

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