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Certain physico-chemical changes in the soil brought about by contamination of crude oil in two oil fields of Assam, NE India

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ABSTRACT

The effect of crude oil spill on soil causes decrease in soil moisture , porosity, water holding capacity, soil pH and extractable phosphorous whereas increase in total nitrogen, organic carbon , exchangeable potassium. Spilled crude oil is certainly responsible for alterations of soil physico-chemical properties.

Key words: Crude oil pollution, soil physico-chemical properties.

INTRODUCTION

Crude oil is not a single chemical but a collection of hundreds of widely different properties and toxicities [1] and when mixed with soil, it changes the physico-chemical changes in the soil. Oil may effects soil in two ways It may penetrate into the soil, where it directly affects plant root system, microbial population and oxygen content. Crude oil in soil makes the soil condition unsatisfactory for plant growth [2], due to the reduction in the level of available plant nutrient or a rise in toxic levels of certain elements such as iron and zinc [3]. Plants are highly susceptible to oil exposure and this may kill them within a few weeks to several months. There are several vegetal species that are capable of growing in soils polluted with hydrocarbons and they participate in their degradation through the rhizosphere, which favours the growth of several microorganisms species [4] and increases biomass and microbial activity, accelerating degradation processes [5]. Alternatively, if oil is stranded on plant shoot, it may reduce the diffusion of oxygen down the plants to the root system; therefore have an indirect effect on soil aeration [6].

North-eastern India, particularly Assam holds a unique position regarding the production of petroleum oil. Crude oil pollution is a regular phenomena in the oil drilling sites as well as the areas through which oil transportation pipelines carries the crude oil either to the oil collecting station (OCS) or to the oil refineries [7, 8, 9, 10, 11 and 12].Survey of literature reveals that very little and scattered information is available of crude oil pollution on soil environment of both temperate and tropical climate. Hence, an effort has been made to investigate factual information regarding crude oil pollution and its impact on soil physico-chemical properties in six crude oil spill areas of two major oil fields of upper Assam has selected.

MATERIALS AND METHODS

Location of study area:
The study area of the present investigation are the Rudrasagar oil field (27 ^{o} 21' N lat. ; 94 ^{o} 62' E long) and Lakwa oil field (27 ^{o} 21' N lat. ; 94 ^{o} 95' E long). Of Sibsagar district of upper Assam, where oil exploration activities are conducted by Oil & Natural Gas Co-operation Limited (ONGCL) .

Demarcation of polluted and unpolluted areas:
The crude oil spilled areas of both the fields were arbitrarily divided into RI, RII and RIII for Rudrasagar oil field and LI, LII and LIII for Lakwa oil field into different spots in order to cover as much as possible areas for study which are commonly suffers from crude oil spills during drilling and transportation processes. To know the changes in soil physico-chemical properties brought about by crude oil spill, one nearby area (control area) of each oil field were also arbitrarily considered as AUAR (Adjacent Unpolluted Areas of Rudrasagar Oil Field) and AUAL (Adjacent Unpolluted Areas of Lakwa Oil Field), where there is no exploration activities and thus free from crude oil spill.

Collection of soil samples:
Soil samples from the study areas were collected at a depth of 0-10 cm. using a soil auger. A total of 24 samples (18 from 6 crude oil spilled areas of two oil fields and 6 from two adjacent unpolluted areas of each oil field) were collected and were taken in polythene begs to the laboratory after labeling them carefully.

Preparation of soil samples:
In the laboratory, the samples were spread on brown paper in the open, when air dried, the samples were ground in a mortar pestle taking the precaution not to break down ultimate particles of soil

Analysis of soil physico-chemical properties:
The colour determination was made on tentative basis by visual observation , soil texture , moisture, porosity and water holding capacity (WHC) were determined according to [13]. Total nitrogen by modified kjeldhal (indophenol) method [14] ; total organic carbon by rapid titration method [15] ; phosphorous by Colorimetric method [16] and Potassium by Flame Photometric method [17].

RESULTS AND DISCUSSION

Physico-chemical properties of all the study areas are given in the Table: 1 and Photographs in 1-6. In crude oil spilled areas the colour of the soil is dark black as against light black in the adjacent unpolluted areas and it may be due to the deposition of crude oil in the spilled areas. Percentage of soil moisture in the crude oil spilled areas are found to be 35.57 ±5.12 and 35.83 ± 6.50 in AR (Polluted areas of Rudrasagar oil field) and AL (Polluted areas of Lakwa oil field) respectively, whereas in the adjacent unpolluted areas it is found to be 43.67 ±7.54 and 44.33 ±7.36 in AUAR (Adjacent unpolluted area of Rudrasagar oil field) and AUAL (Adjacent unpolluted area of Lakwa oil field). As the moisture content are lower (8-9%) in the crude oil crude oil spilled areas in comparison to their adjacent unpolluted areas it can be assured that soil is comparatively drier in affected areas than the unaffected areas because oil which penetrate the soil layer prevent both upward and downward movement of water. Soil surface was drier than lower part of the oil contaminated soil profile [18]. Percentage of porosity in the crude oil spilled areas are found to be 35.83 ± 4.67 and 35.27 ± 4.51 in AR and AL respectively whereas 50.88 ± 1.89 and 50.90 ± 1.71 in AUAR and AUAL respectively shows almost 15% higher porosity values in the adjacent unpolluted areas. Similarly , percentage of water holding capacity (WHC) in crude oil affected areas are found to be lower (26.27 ± 4.84 in the AR and 26.84 ± 4.44 in the AL) as against 48.86 ± 1.15 and 48.78 ± 1.32 in AUAR and AUAL respectively. As the WHC in soil is directly proportional to the porosity, their values are directly depends upon porosity. The lower values of porosity and WHC in the crude oil spilled areas could possibly be due to formation of a thick crude oil coating above the soil surface might have resulted in compactness of soil particles and thus reduces the porosity and WHC of crude oil spilled areas.

Table 1: Soil physico-chemical properties of crude oil spilled areas

A. Physical Properties					
Study area	Colour	Soil texture	Soil Moisture	Soil Porosity	WHC of Soil
AR	Dark Black	Cl=06.67 ± 03.47 Si=21.87 ± 09.78 Sa=71.54± 00.86	35.67 ± 5.12	35.83 ±4.76	26.67 ± 4.83
AUAR	Black	Cl=20.90 ± 04.00 Si=17.52 ± 05.84 Sa=61.57± 05.22	43.67 ± 7.54	50.88 ±1.89	48.86 ± 1.15
AL	Dark Black	Cl=05.94 ± 03.28 Si=24.52 ± 04.61 Sa=69.57 ± 01.91	35.83 ± 6.50	35.27 ±4.51	26.84 ± 4.44
AUAL	Black	Cl=25.70 ± 02.06 Si=13.46 ± 04.07 Sa=60.84± 02.89	44.33 ± 7.63	50.90 ±1.71	48.78 ± 1.32
B. Chemical Properties					
Study areas	pH	Total Nitrogen (%)	Organic carbon (%)	Extractible Phosphorous (ppm)	Exchangeable Potassium (ppm)
AR	5.80 ±0.80	0.12 ± 1.005	8.05 ± 0.99	4.47 ± 1.20	39.63 ± 2.45
AUAR	6.40 ±0.20	0.074 ± 0.007	1.08 ± 0.15	16.00 ± 3.27	29.10 ± 2.25
AL	5.72 ±0.30	0.13 ± 0.007	8.03 ± 0.95	4.45 ± 1.09	41.21 ± 3.06
AUAL	6.36 ±0.20	0.73 ± 0.008	1.07 ± 0.13	16.40 ± 3.17	28.80 ± 3.01

AR: Crude oil spilled areas of Rudrasagar oil field
AL: Crude oil spilled areas of Lakwa oil field
AUAR : Adjacent unpolluted area of Rudrasagar oil field.
AUAL : Adjacent unpolluted area of Lakwa oil field.
Cl= Clay; Si= Silt and Sn=Sand.

Low soil water contents of the crude oil contaminated soil could be due to reduce soil moisture recharge caused by hydrophobic nature of crude oil contaminated soil [2, 19, 20 and 21]. Lower limit of the of the available water in 0-300 meter depth is about 20% volume and upper limit increase from about 40 % volume in the 0-30 cm depth about 42 % volume of 90-100 cm. depth. The air filled pore space would be 10% volume or more when these soils are at field capacity [2]. Investigation on the characteristics of soil in temperate regions changes following contaminated by petroleum oils or gases showed that, many of changes can be related to soil microbial activity [18]. Over 100 species of bacteria, yeasts and moulds are known to attack hydrocarbon. These occur through the range of temperate environmental conditions [22] and microbial activity increase with addition of oil or gases to the soil [23, 24 and 25]. Microbial by product may changes soil moisture retention and release, there by changing the moisture available to plants [22].

Plate 1-3 : Crude oil spilled areas of Rudrasagar Oil Field

Plate 4 -6: Crude oil spilled areas of Lakwa Oil Field

Chemical properties of soil of both affected and unaffected areas are summarized in the Table: 2. The value of pH in the crude oil contaminated areas were found to be 5.80 ± 0.30 and 5.72 ± 0.30 in AR and AL respectively as against 6.40 ± 0.20 and 6.33 ± 0.20 in AUAR and AUAL respectively indicates that crude oil contaminated soil are slightly more acidic in nature may be due to formation of toxic acids in the spilled oils. This finding is in agreement with the earlier findings of [3 and 21]. Usually microbial utilization of hydrocarbon led to formation of organic acids [26]. Thus, the acid probably produced by the microorganisms implicated for reduction in pH levels in crude oil contaminated soil [27].

The percentage of total nitrogen in the crude oil contaminated soil were found to be almost double than their adjacent unpolluted areas. It is found 0.12 ± 0.005 and 0.13 ± 0.007 in AR and AL respectively as against 0.074 ± 0.007 and 0.073 ± 0.008 in AUAR and AUAL respectively. The increase of total nitrogen in crude oil spilled areas may be due to the fixation of atmospheric nitrogen by the microorganisms which assimilated the hydrocarbons [28]. At 10.6% of oil pollution level, the percentage increase attributed to nitrogen content of soil would be 23 what was found in soil amounted to about 62% increase in total nitrogen [3]. Nitrogen is tended to increase in soil which contaminated with oil [29].

Percentage of organic carbon in the crude oil contaminated area was found to be eight (08) times more than unaffected areas. It was found to be 8.05 ± 0.99 and 8.03 ± 0.95 in AUAR and AUAL respectively as against 1.08 ± 0.15 and 1.07 ± 0.13 in AR and AL respectively. This increase was six times more than the corresponding increase in total nitrogen. Obviously, these increases were attributable to the carbon from the spilled crude oil. Increase of organic carbon is directly proportional to the increase of crude oil addition to the soil [3]. The high C/N ratios leading to immobilization of soil nitrates coupled with the environment brought about by the oil pollution, accounted for low level of NO_3-N in the oil contaminated soil. Highly crude oil contamination soil exhibit more organic carbon than the less crude oil contamination soil [21].

Extractable Phosphorus was found to be four times less in the crude oil affected areas than the unaffected areas. It was found to be 4.47 ± 1.20 and 4.45 ± 1.09 ppm in AR and AL respectively as against 16.00 ± 3.24 and 16.40 ± 3.17 ppm in AUAR and AUAL respectively. The reduction in the extractible phosphorus in the crude oil contaminated areas is probably due to high C/P ratio resulting from the crude oil addition. Assam petroleum crudes contained negligible amount of phosphorus [30], the microorganisms which attack the hydrocarbons would immobilize the inorganic phosphorous in the soil thus bringing about a reduction in extractible phosphorous. This is in agreement with the earlier findings of [3 and 31] but is contrary to that of [2 and 24]. Available phosphorous increased in natural gas polluted soil and increased with oil contamination [24].

Exchangeable potassium (k^+) is found to be slightly high in the crude oil affected areas than the unaffected areas. It is found to be 39.63 ± 2.45 and 41.21 ± 3.66 ppm in AR and AL respectively as against 29.10 ± 2.25 and 28.80 ± 3.01 ppm in AUAR & AUAL respectively. It ca be assumed that a higher rate of potassium in the crude oil spilled areas near the oil well may be due to the deposition of more potassium present in the deeper soil layers which comes upward during the crude oil drilling operation and remains deposited in the upper soil layer near the drilling point. Moreover, it may be attributed to leakage of saline effluent along with crude oil; ionic concentration may build up resulting in more k in crude oil contaminated soil [21 and 32] .

CONCLUSION

It is concluded from the above study that crude oil certainly responsible for alterations of soil physico-chemical properties, destroy the seed bank, habitats of micro flora and fauna, vegetation , hurdles in nutrient cycling, energy flow results in lowering the complexity of terrestrial ecosystem and produced a physically controlled ecosystem rather than a biologically controlled ecosystem by reduction in species diversity. So, it is utmost necessary to take some perfect steps either to control or to minimize the crude oil pollution in this region, where, hectic oil exploration activities has recently been geared up in various oil fields.

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