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Physicochemical and mineral content analyses of soils and *Mangifera indica* stem bark obtained from crude oil-polluted and crude oil free environments

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Abstract
The adverse effects of crude oil exploration and extraction on the health of exposed individuals cannot be overstated. The use of crude oil-contaminated plant extracts by rural communities in oil-rich regions as traditional remedies has raised significant local and international concerns regarding safety. This study aimed to evaluate the physicochemical properties of plant extracts and soils obtained from both uncontaminated and oil-contaminated environments. Crude aqueous extracts of *Mangifera indica* stem bark, contaminated with crude oil, were collected from an oil spill site in Ihuaba/Imogu in Elele Alimini, Ikwerre, Rivers State, Nigeria, while control samples were obtained from the University of Benin, an uncontaminated location in Ugbowo, Benin City, Edo State. The pH, color, texture, odor, moisture content, and mineral composition of soil and plant samples were analyzed using AOAC standard methods. Results indicated that physicochemical properties such as moisture content and bulk density significantly increased ($p<0.05$), while pH significantly decreased ($p<0.05$) in crude oil-contaminated soil. Additionally, essential elements like phosphorus, calcium, and magnesium significantly decreased ($p<0.05$), whereas lead and chromium concentrations significantly increased ($p<0.05$) in crude oil-contaminated soil and plant samples compared to those in uncontaminated soil and plant samples.

Keywords: *Mangifera indica*, tannins, flavonoids and wistar albino rats

Introduction

Crude oil, also known as petroleum, is a naturally occurring, flammable liquid found in rock formations within the earth. It is composed of a complex mixture of hydrocarbons along with various organic compounds of differing molecular weights. Crude oil serves as the most significant source of hydrocarbons. Crude oil is generally classified by sulfur content and density, with density measured in API (American Petroleum Institute) gravity. Light crude, characterized by a higher API gravity (typically greater than 40), has a lower density, while heavy crude, with an API gravity below 20, has a higher density. Thus, a higher API gravity indicates a lower density. Brent crude, a major benchmark, has an API gravity between 38 and 39. Crude oil is further categorized as "sweet" or "sour" based on sulfur content, which also influences its aroma. Sweet crude has less than 0.5% sulfur, making it more environmentally and engine-friendly, whereas sour crude contains a higher sulfur content, contributing to its ecological harm (Lin and Tamvakis, 2001) [2]. The hydrocarbons in crude oil are typically alkanes, cycloalkanes, and various aromatics. Although the molecular composition varies among oil formations, the proportion of chemical elements remains consistent. Crude oil pollution is known to negatively impact plant germination and seedling growth (Kyung-Hwa *et al*., 2004) [4]. The environmental and ecological damage caused by oil spills, especially in Nigeria's Niger Delta, creates lasting threats to biodiversity and human health. Spilled oil contaminates surface water, endangers marine life, and disrupts the interconnected food chain. In this study, *Mangifera indica* from both contaminated and uncontaminated environments will be administered to Wistar albino rats to observe the biochemical effects of these substances on the rats' overall health (Percival and Evans, 1997) [5].

Materials and Methods

Chemicals

All the chemicals and reagents used were of analytical grade obtained from m/s Merck India, Ltd. Bombay. Distilled water and acid washed glassware were used throughout the analysis.

Collection of plant

The plant samples were collected from Ihuaba/Imogu in Elele Alimini, located in Ikwerre, Rivers State, Nigeria, at longitude 6.7307°E and latitude 5.0588°N. The Ikwerre Local Government Area (LGA) was randomly selected due to its high incidence of crude oil spills, with a significant spill recorded in February 2017. This incident involved approximately 155.65 barrels of crude oil, contaminating around 800 square meters of farmland with an oil infiltration depth averaging 0.4 meters below the surface (Okonta and Oronto-Douglas, 2001) [6]. Stem bark from *Mangifera indica* and soil samples were collected from this farmland at soil depths of 15-30 cm, using a soil auger, eight months after the oil spill. Control samples were obtained from the University of Benin, an uncontaminated site. The collected stem bark and soil samples were placed in large cement bags, rinsed with purified water, and stored in sterile polyethylene containers. The samples were then sealed, labeled, and verified in the Department of Plant Biology and Biotechnology, where a voucher number, UBHM 0249, was assigned by Dr. Akinnibosun Henry.

Preparation of Crude Drug Powder

Stem bark from *Mangifera indica* (sourced from both contaminated and uncontaminated areas) was collected, cut into smaller pieces, and air-dried for two weeks. Once dried, the bark was ground and sieved to obtain a coarse powder**.**

Physicochemical and Mineral Content Analysis of Plant Species

The pH, color, texture, odor, moisture content, and mineral composition of soil and plant samples were evaluated according to AOAC standard methods (1990) [7].

Procedure

Two grams of oven-dried plant sample were digested on a hot plate with 12 ml of a di-acid mixture (a 2:1 ratio of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$)) at 120 °C for 15 minutes until frothing ceased. After cooling to room temperature, the solution was filtered into a conical flask, diluted to 50 ml with deionized water, and stored in a 50 ml container with bumping chips to prevent boiling. The digested samples were analyzed using a Varian Atomic Absorption Spectrophotometer (FS 240) (AOAC, 1990) [7].

Statistical Analysis

All data obtained were statistically analyzed using the student's t-test in SPSS (version 12.0 for Windows). Results were presented as mean ± standard error of the mean (SEM), with a significance level set at $p<0.05$.

Result

The findings presented in Table 4.1 demonstrate noteworthy significant ($p<0.05$) changes in the physicochemical properties of soil and plants contaminated with crude oil. Furthermore, the levels of essential elements, including phosphorus, sulfur, calcium, magnesium, iron, and zinc, were significantly reduced in both crude oil-contaminated soil and plant samples compared to crude oil free soil and plants ($p<0.05$).

Table 1: The physicochemical properties and mineral contents of the contaminated and uncontaminated plants and soils

Physicochemical Parameter																		
Test samples	**Appearance**	**Odor**	**pH of 10% solution**	**Bulk density (g/cm^3)**	**Porosity (%)**	**Moisture content (%)**	**THC (%)**	**Nitrate (m/kg)**	**P (m/kg)**	**S (m/kg)**	**Cl (m/kg)**	**Ca (m/kg)**	**Mg (m/kg)**	**Cu (m/kg)**	**Ch (m/kg)**	**Fe (m/kg)**	**Pb (m/kg)**	**Zn (m/kg)**
Normal soil (F)	Reddish brown	Odorless	6.30	1.11	2.22	1.48	0.21	400.00	10.30	80.00	450.00	170.00	42.00	5.80	0.46	145.80	0.62	3.10
Crude oil polluted soil (C)	Dark brown	Oil odor	5.84	1.18	2.86	3.12	9.68	30.00	0.20	540.00	549.83	110.00	38.00	6.10	0.59	79.30	0.65	3.20
Plants from crude oil free environment	Dark tan	-----	6.53	------	-------	16.97	1.28	1050.00	80.00	650.00	1249.60	1110.00	390.00	0.11	ND	15.20	ND	2.70
Plants from crude oil contaminated environment	Light shade of tan	------	6.35	--------	-------	15.12	2.07	250.00	63.00	900.00	600.00	996.00	310.00	0.28	ND	2.40	0.82	2.92

KEY:

THC= Total Hydrocarbon Content; S = Sulphate; Cl= Chloride; P= Phosphate; Ca= Calcium. Cu= Copper; Ch= Chromium; Fe= Iron; Pb= Lead and Zn= Zinc

F= Uncontaminated sample.

C= Crude oil contaminated sample.

Discussion

The results revealed significant changes in the physicochemical parameters of soil and plant samples. The appearance and odor of the soil and plants not contaminated by crude oil were notably different from those affected by crude oil pollution. These differences in appearance and odor may be attributed to the presence of crude oil. The pH of soil and plants free from crude oil contamination was higher than that of the crude oil-polluted samples. This observation could be explained by the natural acidity of crude oil and aligns with the findings of Rahman *et al.* (2001) [9] and Noshin *et al*. (2021) [8], who reported that crude oil contamination significantly alters soil properties, including pH, electrical conductivity, and organic matter content. Increased bulk density, particle size, and total hydrocarbon content in crude oil-polluted soil, compared to uncontaminated soil, may result from crude oil filling soil pore spaces and the high hydrocarbon content inherent in crude oil. The increase in bulk density corroborates the findings of while the elevated hydrocarbon content is consistent with Ekundayo and Obuekwe (2000) [15]. Additionally, the rise in moisture content in the crude oil-polluted soil, compared to uncontaminated soil, could be due to stagnant surface water induced by crude oil presence. Conversely, the reduced moisture content in crude oil-polluted plants might result from stress caused by crude oil, which may impair water transport through xylem tissues. These observations align with those of Peretiemo-Clarke and Achuba (2007) [10]. The observed reduction in macronutrients, such as calcium, nitrate, phosphate, chloride, and magnesium, in crude oil-polluted soil and plants, compared to uncontaminated samples, may be due to the acidic environment created by the crude oil, which inhibits nutrient uptake. This decrease in macronutrient availability is consistent with findings by Athar *et al*. (2016) [11] and Nwaogu and Ujowundu (2010) [12]. Conversely, the increase in sulfur content in contaminated soil and plants could be attributed to the high sulfur levels in crude oil. Additionally, elevated heavy metal levels (e.g., zinc, lead and copper) in crude oil-polluted plants and soil, compared to uncontaminated samples, likely stem from the presence of these metals in crude oil, which may have leached into the soil. *Mangifera indica* plants may exclude or degrade iron while accumulating more zinc, chromium, and copper in their tissues, a finding supported by Ogbuehi *et al*. (2010) [13], who reported that certain plants can phytoextract heavy metals from crude oil-polluted soils. Consistent with the observations of Otitoju *et al*. (2017) [14], crude oil pollution results in the absorption of pollutants, including some aliphatic and aromatic hydrocarbons, into plant cells or tissues, leading to the formation of free radicals in plants growing in contaminated environments.

Conclusion

The findings of this study, together with prior research, suggest that hydrocarbons in crude oil can have a significant impact on the health and growth of living organisms, including plants.

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