

Original Research Article

Environmental impact of crude oil on the phytochemical constituents of some selected medicinal plants in Nigeria

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Abstract

Purpose: To investigate the effect of crude oil exploration on secondary metabolites of *Magnifera indica*, *Ficus exasperata*, *Mallotus oppositifolius*, *Millettia aboensis* and *Newbouldia leavis*.

Methods: The leaves of the plants were collected from Ogoni (oil-producing area) referred to as test samples, and Awka (non-oil-producing area) referred to as control, in Nigeria. Methanol and dichloromethane extracts of the leaves of the plants, harvested from both regions, were subjected to phytochemical analyses and gas chromatography/mass spectrometry (GC-MS) analysis. Quantification of the phytochemicals was done spectrophotometrically and expressed as equivalent to their respective standards.

Results: Extraction yield ranged from 4.4 to 10.4 %w/w. Phytochemical analysis showed that all the test phytochemicals, except cyanogenic compounds, were detected in both test and control samples. Steroids and alkaloids were significantly higher in test samples compared to control samples ($p < 0.05$). Furthermore, terpenoid was significantly lower ($p < 0.05$) in test samples (*F. exasperata* and *M. oppositifolius*) than in control samples. The GC-MS analysis revealed that only *M. indica* contained 1,3-diazocane-2-thione and 5-methyl-1,2-oxazol-3-amine were present in both the test and control samples, while the other samples contained diverse alkaloidal chemotypes.

Conclusion: The multifactorial nature of oil exploration may affect plant phytochemicals via chemical transformation, depletion or accumulation. This provides valuable insights into the need for environmental conservation.

Keywords: Crude oil exploration, GC-MS, Ogoni, Secondary metabolites, Quantitative phytochemical

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INTRODUCTION

Ogoni, an oil-rich area in Nigeria, serves as a reservoir of a rich flora that has played a significant role in traditional healthcare of its

indigenous communities. The impact of environmental factors such as soil conditions, water table and air pollution on the survival, growth and efficacy of medicinal plants is enormous [1]. Over the years, the growing crude

oil exploration activities have continued to disrupt the original ecosystem, with potential consequences on phytochemistry [2]. The potential effects on the phytochemical composition and efficacies of medicinal plant species are both underexplored and urgently require attention [2]. The complex, delicate equilibrium between oil exploration and the phytochemistry of plants raises questions about the survival of traditional healing practices and health of people who depend on these plants [1]. This study selected five medicinal plants with validated activities commonly utilized in folkloric medicine in Ogoni and Awka regions of Nigeria [3].

In this study, Awka represented a non-oil-producing region in Southeastern Nigeria. The plants included: *Magnifera indica* (*M. indica*; Anacardiaceae), *Ficus exasperata* (*F. exasperata*; Moraceae), *Mallotus oppositifolius* (*M. oppositifolius*; Geiseler) Mull (Euphorbiaceae), *Millettia aboensis* (*M. aboensis*; Fabaceae), and *Newbouldia laevis* (*N. laevis*; Bigoniaceae). The plants were selected based on their availability in both regions in the same season, common uses in both regions and other ethnopharmacological data gathered from traditional medicine healers in both regions [3]. In ethnomedicine, decoction of the leaves of *M. indica* is a remedy for fever, chest pain, diabetes and hypertension and possesses antifungal, antiviral, hepatoprotective and anticancer activities [4]. The magniferin content is a strong astringent and is used for the treatment of rheumatism and diphtheria, diarrhea and chronic dysentery [4].

The *M. oppositifolius* leaves is a multi-active medicinal plant. The infusion is a worm-expeller, pain relief used for anemia, urinary infections, malaria, leprosy, chickenpox, dysentery and diarrhea, pneumonia, convulsions, stomachache and lumbago [5]. It possesses aphrodisiac, hemostatic and anti-venom activities [5]. The anti-ulcer, antimicrobial, antiparasitic, antiviral, anticancer and antidiabetic activities of the leaves of *M. aboensis* have been reported [6]. Various parts of *N. laevis* are effective in diarrhea, dysentery, paralysis, epilepsy, convulsions, spasms, arthritis and rheumatism. They are used as antimicrobials, antidotes and anti-abortion agents [7].

Leaves of *Ficus exasperata* are used as an antiulcer, hypotensive, lipid-lowering, analgesic and antipyretic agent [8]. In most cases, the plants have the same ethnomedicinal effect across Southern Nigeria, where the study was carried out, with no significant variations. The

hazardous effects of oil spillage on aquatic and human lives are known, and the likelihood that it will pose a threat to plants is high. The residue from a spill adheres to plants and blocks their ability to get carbon dioxide or block out sunlight from reaching the leaves, which are vital ingredients in photosynthesis [9].

Reports have shown that oil residues may penetrate the intercellular spaces and vascular system and block stomata and intercellular spaces [10]. Despite the numerous data on the hazardous effects of oil exploitation, there have not been studies to establish its relationship with phytoconstituents of medicinal plants. The study, therefore, investigated the effect of crude oil exploration in Ogoni on the phytoconstituents of *M. indica*, *F. exasperata*, *M. oppositifolius*, *M. aboensis*, and *N. laevis* compared to species from non-oil-producing region.

METHODS

Plant samples

The leaves of *Magnifera indica*, *Ficus exasperata*, *Mallotus oppositifolius*, *Millettia aboensis* and *Newbouldia laevis* were used for the studies. A total of 10 samples (5 plants from each zone) of the medicinal plants were randomly collected from Ogoni zone (GPS location: lat. 4.7810238; long. 7.1547854), Rivers State constituting the test samples and Awka zone (GPS location: lat. 6.2069444; long. 7.0677778) in Anambra State of Nigeria constituting the control samples, based on their ethnomedicinal relevance as antimicrobial medicinal plants. The plants were harvested in May 2022. The plant samples were collected in plastic containers each holding 500 g of the sample. A taxonomist, Mr Alfred Ozioko of the International Centre for Ethnomedicine and Drug Development (InterCEDD), Nsukka, Nigeria, authenticated the samples. The specimens for *M. indica*, *F. exasperata*, *M. oppositifolius*, *M. aboensis*, and *N. laevis* with voucher ID (InterCEDD/884, InterCEDD/885, InterCEDD/886, InterCEDD/887 and InterCEDD/888), respectively, were retained in the laboratory for reference. The plants were dried in the shade in a well-ventilated room for 5 weeks. The dried leaves were ground to a coarse powder using a mechanical grinder (G×160 Delmar 5.5 HP).

Preparation of plant extract

A coarsely powdered dry sample (500 g) of each plant from both zones was macerated separately in 2 L of methanol/dichloromethane (1:1) in a

closed jar with periodic agitation for 48 h [11]. After filtration, the marc was macerated again in 2 L of the same solvent for 24 h with intermittent agitation. The combined filtrate was concentrated in a rotary evaporator at room temperature to obtain extracts of *M. indica*, *F. exasperata*, *M. oppositifolius*, *M. aboensis*, and *N. laevis* from each zone.

Qualitative phytochemical analysis

Alkaloids, glycosides, saponins, tannins, flavonoids and terpenes were identified using previously described standard techniques [11].

Quantitative phytochemical analysis

Quantification of the secondary metabolites in the samples was carried out using previously described standard techniques [12]. Alkaloid content was determined by acid digestion with 20 % H_2SO_4 for 3 h, followed by 60 % H_2SO_4 . Total alkaloid was calculated from the atropine standard regression equation at 490 nm. Total saponin was determined using the vanillin–sulfuric acid assay, with the absorbance measured at 527 nm. Tannin content was measured at 530 nm within 10 min using tannic acid as a reference standard. To determine steroids, a 1 mg extract was mixed with H_2SO_4 (4 N, 2 mL), FeCl_3 (0.5 % w/v, 2 mL) and potassium hexacyanoferrate (III) solution (0.5 % w/v, 0.5 mL). The absorbance was measured at 780 nm against a cholesterol standard calibration. Terpenoid content was determined by mixing the extract with phosphomolybdic acid, followed by concentrated H_2SO_4 and the absorbance was read at 700 nm using a cholesterol standard. The AlCl_3 colourimetric method was used to estimate total flavonoid content by measuring the optical density relative to the control at 510 nm for 15 min with a rutin standard. The Folin-Ciocalteu method was used to determine the total phenol of the extracts at 650 nm using a gallic acid calibration curve. To estimate the cyanogenic glycosides, alkali picrate solution was added to the extract and boiled for 5 min at 90 °C, and the absorbance of the mixture was measured at 490 nm.

Gas chromatography-mass spectrometric (GC-MS) analysis

The extract (50 mg/mL in 95 % methanol/dichloromethane (DCM)) was subjected to GC-MS analysis using the GC-MS/Electron Impact method (Sciex 436-GC Bruker model paired with an MS quadrupole phase spectrometer) with a fused silica capillary column BR-5MS (5 % diphenyl/95 % dimethyl

polysiloxane) to dimensions of 30 m in length, 0.25 mm in internal diameter, and 0.25 μm in thickness [13]. With a total injection volume of 2 μL and a split ratio of 10:1, helium gas (99.999 %) was utilized as a carrier gas at a steady flow of 1 mL/min under standard conditions (temperature of the ion source was 280 °C, injector was 250 °C and oven was set to start at 110 °C (isothermal for 2 min), rose by 10 °C/min to 200 °C and then increased by 5 °C/min to 280 °C; furnace was allowed to operate for 41 min, following a 9 min isothermal period at 280 °C, ionization energy of 70 eV, mass spectrometer was run in the positive electron ionization (EI) mode, delay in the solvent was 0 - 3.0 min, scan interval of 0.5 s and fragments from m/z 50 to 500 Da were programmed, temperature of 280 °C was set for the inlet and 250 °C for the source). By comparing the average peak area of each component to the total areas, the proportion was determined. MS WorkStation 8 was the program used to manage the chromatograms and mass spectra. Chemical components were identified using the NIST Version 2.0 library database of the National Institute of Standards and Technology (NIST), which contained more than 62,000 patterns [13].

Data analysis

Data was analyzed using Statistical Packages for Social Sciences (SPSS version 22.0, IBM, Armonk, NY, USA). Results of the quantitative phytochemical composition were presented as mean $\pm$ standard error of the mean (SEM) and analyzed with one-way analysis of variance (ANOVA). $P < 0.05$ was considered statistically significant.

RESULTS

Extraction of plant sample

Cold maceration of dried coarse samples in methanol/dichloromethane (1:1) yielded extracts in different proportions (Table 1). There was no significant difference in yield of the extracts between test and control samples ($p > 0.05$).

Qualitative phytochemical content

Composition of the secondary metabolites showed the presence of alkaloids, flavonoids, tannins, saponins, total phenolics, terpenoids and steroids in all the samples. There were variations in colour intensity and/or the precipitate formed in the test. Cyanogenic compounds were absent.

Table 1: Extraction yields of studied plant samples

Plant sample	Yield (g)	Yield (%w/w)
<i>F. exasperata</i> (S)	42.5	8.5
<i>F. exasperata</i> (C)	40.5	8.1
<i>M. indica</i> (S)	52.0	10.4
<i>M. indica</i> (C)	49.5	9.9
<i>M. aboensi</i> (S)	22.0	4.4
<i>M. aboensi</i> (C)	25.5	5.1
<i>M. oppositifolius</i> (S)	39.0	7.8
<i>M. oppositifolius</i> (C)	37.5	7.5
<i>N. laevis</i> (S)	33.0	6.6
<i>N. laevis</i> (C)	35.0	7.0

Study sample (S), control sample (C)

Variation in phytochemical content of plants

Variations in phytochemical composition of plants harvested within the oil exploration area of Ogoni were evaluated relative to the control region. There was significantly higher ($p < 0.05$) steroid content in *M. indica*, *M. oppositifolius* and *N.*

laevis samples while a significantly lower ($p < 0.05$) content was obtained in *F. exasperata*. There was no significant difference in the steroidal composition between test and control samples of *M. aboensi* ($p > 0.05$). Terpenoid was significantly lower ($p < 0.05$) in the test *F. exasperata* and *M. oppositifolius* and no significant difference in *M. indica*, *M. aboensi* and *N. laevis* samples ($p > 0.05$). Saponin was significantly higher ($p < 0.05$) in *M. oppositifolius*, *M. indica*, and *M. aboensi*, with no difference in the others ($p > 0.05$). Total phenolics were significantly higher ($p < 0.05$) and lower in *M. oppositifolius* and *N. laevis*, respectively, with no significant difference in other plants. Both tannins and flavonoids were significantly higher ($p < 0.05$) in all test samples compared to control. However, alkaloids were significantly higher in test sample of *F. exasperata* and *M. aboensi*, with no significant difference ($p > 0.05$) in other plants (Figure 1).

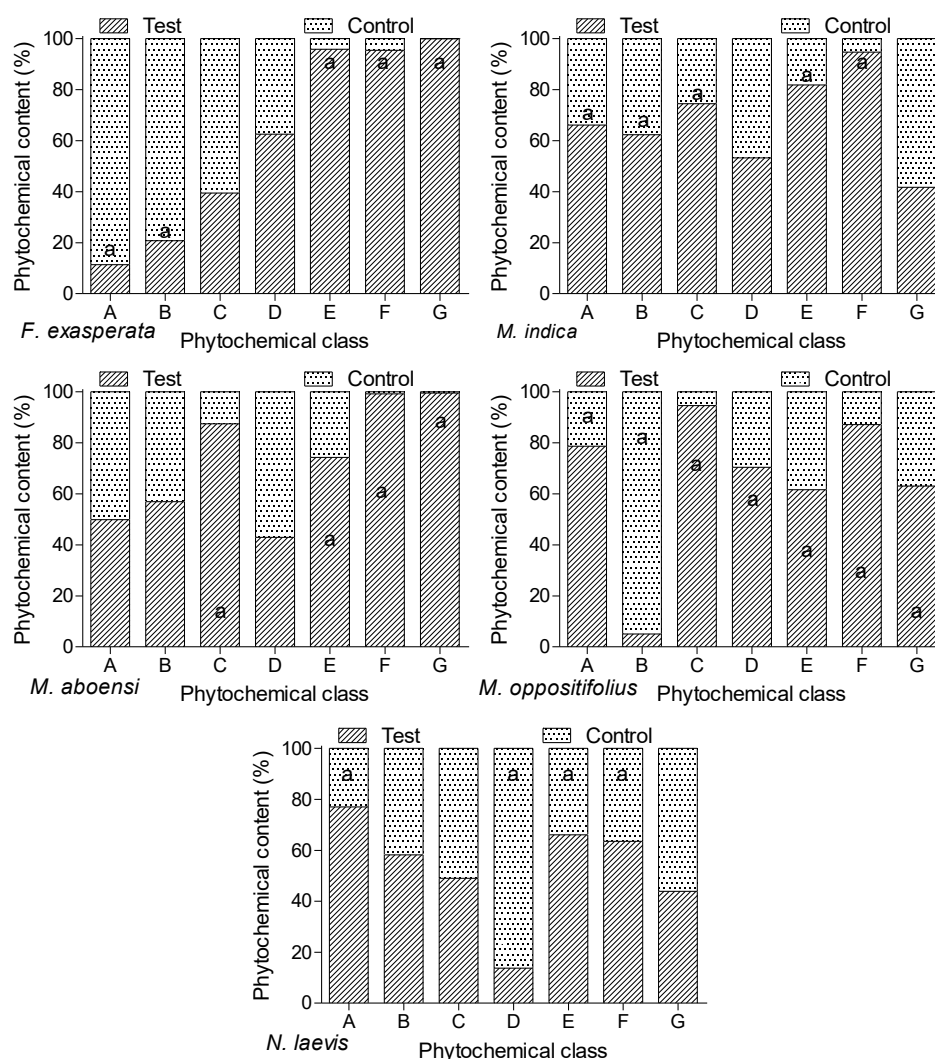


Figure 1: Phytochemical composition of the five plants studied. ^a $P < 0.05$ showed a significant difference between the phytochemical content of test and control samples. Steroids (A), terpenoids (B), saponins (C), total phenolics (D), tannins (E), flavonoids (F) and alkaloids (G)

GC-MS analysis of the extracts

The GC-MS analysis of the extracts of both test and control samples of *M. aboensi* showed a relatively common fragmentation pattern with varying peak areas. Two alkaloidal markers each were identified from the test (4-Hydroxy-1-methylproline (T1) and 5-hydroxypipericolic acid (T2)) and control samples (1-butylimidazole (C1) and 4-methyl-1-(1-phenylethenyl)-5-(pyrrolidin-1-yl)-4,5-dihydro-1*H*-1,2,3-triazole (C2)).

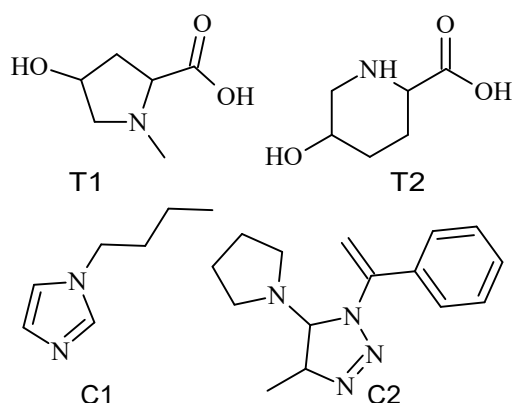


Figure 2: Identified compounds from *M. aboensi*; test plant (T); control plant (C); 4-hydroxy-1-methylproline (T1), 5-hydroxypipericolic acid (T2), 1-butylimidazole (C1), 4-methyl-1-(1-phenylethenyl)-5-(pyrrolidin-1-yl)-4,5-dihydro-1*H*-1,2,3-triazole (C2)

The GC-MS analysis of the extract of *F. exasperata* detected 11 phytochemical markers

in both the test and control samples, comprising 9 (T3-T11) and 2 (C3-C4) alkaloids, respectively (Figure 3). The compounds included *N*-(propanoyloxy)-1,2,4-oxadiazole-3-carboximidamide (T3), pyrimidine-2,4,5-triol (T4), thiomorpholine-3-carboxamide (T5), *N,N*-diethylnitrous amide (T6), 1-(2-(2-methyl-5-oxo-4-propyloxolan-2-yl)-2-oxoethyl)-1,2-dihydropyridazine-3,6-dione (T7), 1-(4-ethyl-2,5-dimethoxyphenyl)propan-2-amine (T8), 5-ethenyl-5-(pent-4-en-2-yl)-1,3-diazinane-2,4,6-trione (T9), 4-amino-5-methylpyrimidine-2(1*H*)-thione (T10), 1,3-diazocane-2-thione (T11), phenyl carbamate (C3) and (pyridin-3-yl)methyl acetate (C4).

The GC-MS analysis of the extract of *M. indica* identified three markers each from the test and control samples (Figure 4). The markers identified from the test extract included methyl *N*-hydroxybenzenecarboximidate (T12), 2,5-dihydro-1*H*-pyrrole-2-carboxylic acid (T13) and 1,3-dimethyl-1,3-diazinane-2-thione (T16) from the test *M. indica* while methyl *N*-hydroxybenzenecarboximidate (C5), *N*-((*E*)-(3,4-dimethyl-1*H*-pyrrol-2-yl)methylidene)hydroxylamine (C8) and 1-pyrrolidinebutanoic acid derivative (C9) were detected from the control *M. indica*. The two compounds, 1,3-diazocane-2-thione (T14/C7) and 5-methyl-1,2-oxazol-3-amine (T15/C6), were found in both samples.

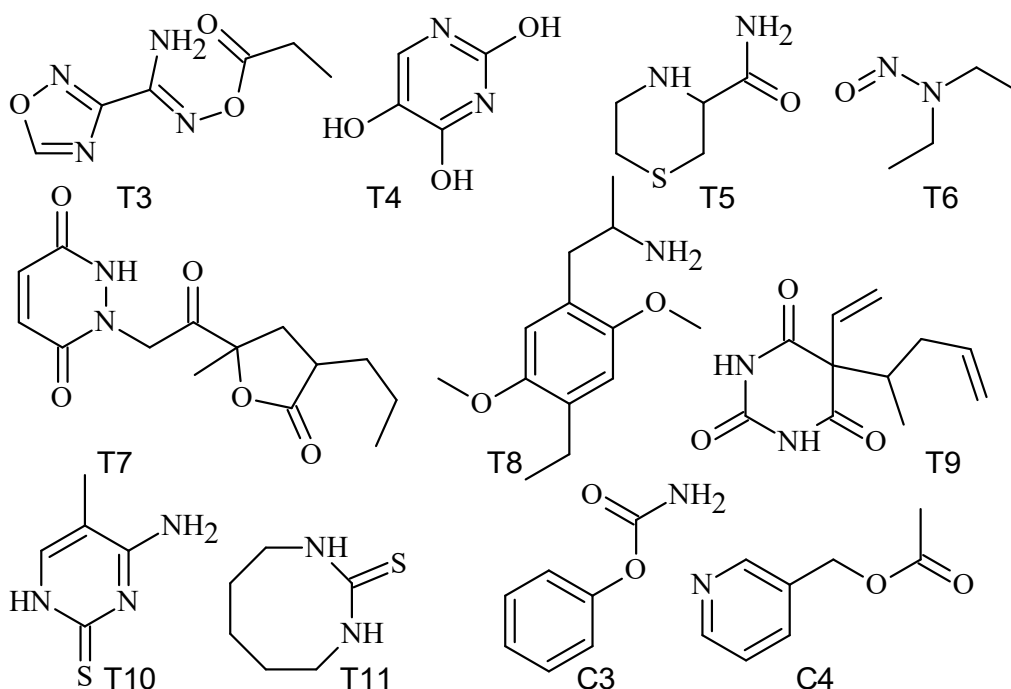


Figure 3: Identified compounds from *F. exasperata*; test plant (T); control plant (C)

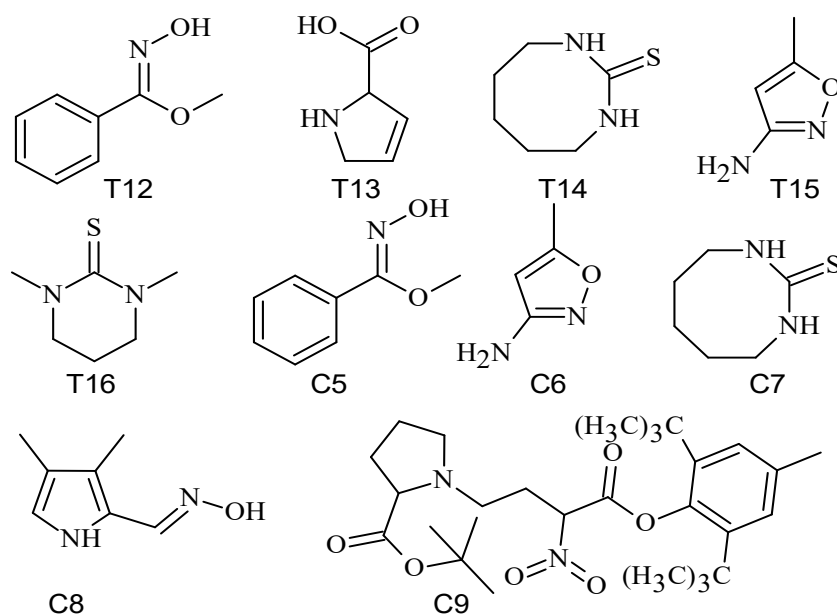


Figure 4: Identified compounds from *M. indica*. Test plant (T), control plant (C)

Twelve markers (T17-T28) were obtained from the extract of test *M. oppositifolius*, while four (C10-C13) were identified from control sample (Figure 5). Identified compounds included 2,5-dihydro-1*H*-pyrrole-2-carboxylic acid (T17), 1-(1-ethyl-1*H*-pyrazol-4-yl)methanamine (T18), (2*E*)-1,1-diethyl-4,4-dimethyltetraaz-2-ene (T19), 1,3-diazocane-2-thione (T20), butyl 2-((ethoxycarbonyl)amino) pentanoate (T21), 1*H*-pyrrole-2-carboxamide (T22), 3,4-dimethylquinolin-2(1*H*)-one (T23),

2,8-dimethylquinolin-4-ol (T24), 2,5-dimethyl-5*H*-(1,3)thiazolo(3,2-*a*)pyridin-8-ol (T25), 6-methoxypyridin-2-amine (T26), (6-methylpyrazin-2-yl)methanol (T27), 2-ethoxy-3-ethylpyrazine (T28), 1-pyrrolidinebutanoic acid derivative (C10), 1-((*E*)-(4,7,7-trimethylbicyclo(4.1.0)hept-4-en-3-ylidene)amino)oxy)ethan-1-one (C11), 2,2'-disulfanediyldis(5-methoxypyrimidine; C12) and *N*-(1,1-dihydroxy-3-(propyldisulfanyl)propan-2-yl)acetamide (C13).

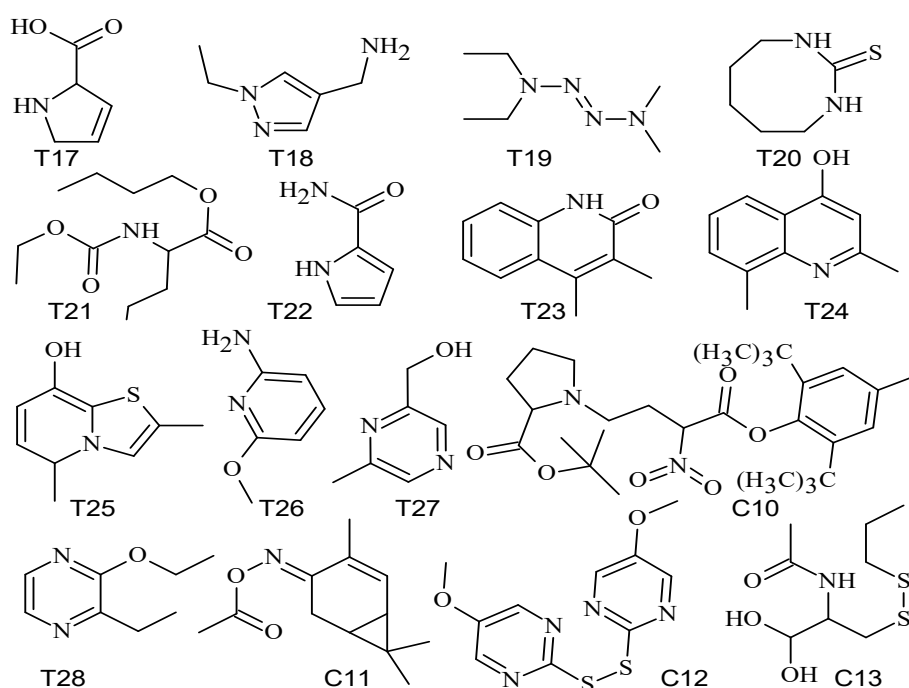


Figure 5: Identified compounds from *M. oppositifolius*; test plant (T); control plant (C)

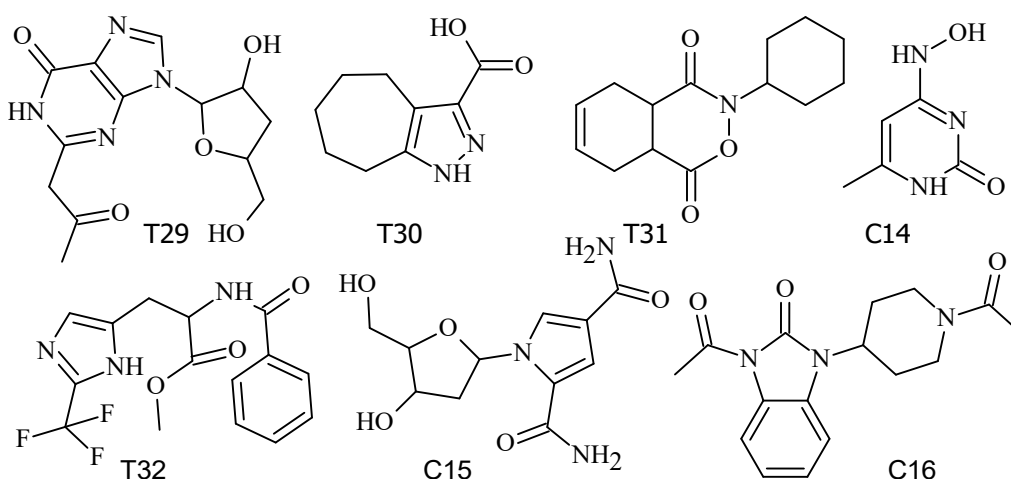


Figure 6: Identified compounds from *N. laevis*; test plant (T); control plant (C)

GC-MS analysis identified four (T29-T32) and three (C14-C16) markers in the test and control samples of *N. laevis* extract (Figure 6). The markers included 9-(3-hydroxy-5-(hydroxymethyl)oxolan-2-yl)-2-(2-oxopropyl)-1,9-dihydro-6*H*-purin-6-one (T29), 1,4,5,6,7,8-hexahydrocyclohepta(c)pyrazole-3-carboxylic acid (T30), 3-cyclohexyl-4a,5,8,8a-tetrahydro-1*H*-2,3-benzoxazine-1,4(3*H*)-dione (T31), methyl 2-benzamido-3-(2-(trifluoromethyl)-1*H*-imidazol-5-yl)propanoate (T32), 4-(hydroxyamino)-6-methylpyrimidin-2(1*H*)-one (C14), 1-(4-hydroxy-5-(hydroxymethyl)oxolan-2-yl)-1*H*-pyrrole-2,4-dicarboxamide (C15), 1-acetyl-3-(1-acetyl piperidin-4-yl)-1,3-dihydro-2*H*-benzimidazol-2-one (C16).

DISCUSSION

Despite the wealth of knowledge regarding the impact of crude oil on plant physiology, a notable deficiency exists in the understanding of how such environmental stressors influence the phytoconstituents of some medicinal plants, in the specific context of the Ogoni area. The complexity of this impact necessitates a focused exploration to bridge this gap, offering insights that are pertinent and crucial for sustainable environmental and healthcare practices within the region. Over a specific period, plants convert sunlight and carbon dioxide (CO₂) to energy under ambient temperatures [11]. The hydration needed by a plant is determined by the conductance of stomatal cells, and leaf area and by external factors like wind, light and air humidity. Crude oil explorative activities cause oil spills, which usually occur with CO₂ release. Several releases of this substance in an environment create a rise in the temperature of the environment, thus distorting photosynthetic and biosynthetic processes [12].

Extraction techniques and extracting solvents play vital roles in natural medicinal product chemistry, especially in environments affected by crude oil exploration and oil spillage. The cold maceration method, which involves soaking plant material in a solvent over time, preserves the phytochemicals, especially the volatile constituents and since they are unknown in the plants, maceration thus serves as the best extraction technique. The choice of solvents significantly impacts the yield as solvents of varying polarities control their ability to extract specific phytochemicals [14]. The combined methanol-dichloromethane (DCM) used in this study could offer extraction of a broader solvent range of both polar and non-polar compounds, improved efficiency by simultaneously targeting different phytochemicals, reduced thermal degradation of heat-sensitive phytochemicals due to the low boiling point of DCM, ease of evaporation and versatility due to their use in maceration, percolation and Soxhlet techniques [15].

The polarity of extracting solvents and the extraction technique determine the efficiency and specificity of the phytochemical extraction procedure, particularly in oil exploration environments where the extraction process must be optimised to minimise contamination [14,15]. In this study, except for the cyanogenic compounds, all the tested secondary metabolites were detected in both the test and control extracts. Since the tests were qualitative, the effect of oil exploration or spillage on the secondary metabolites could not easily be ascertained, considering the possibility of chemical transformation of one phytoconstituent to another [2,16]. The overall effect, however, depends on the phytochemical reserve in the plants or the phytochemicals accumulated over

time. The qualitative test performed in this study, however, does not resolve this limitation.

The impact of oil exploration and other environmental factors on the quantitative phytochemical constituents of selected medicinal plants in Ogoni land (test) compared with Awka (control) in Nigeria showed a non-uniform trend. The most significant impacts were recorded in *F. exasperata* and *M. oppositifolius* with higher total phenolics, tannins, flavonoids and alkaloids content in the test plants than in the control. In both plants, lower terpenoids were found in the test plants. There was relatively equal content of total phenolics in *M. indica* (49.75 vs 43.77 g/100g); steroids in *M. aboensis* (27.21 vs 27.23 µg/100g) and saponins in *N. laevis* (16.86 vs 17.53 mg/100g) in both test and control plants, respectively. In all the cases, traces of alkaloids were detected in the test samples of *F. exasperata* (25.34 vs 27433.99 mg/g) and *M. aboensis* (17.02 vs 3293.46 mg/g) as well as flavonoids in *M. aboensis* (12.06 vs 1494.21 mg/g) which corroborated the results of the qualitative analysis where all the secondary metabolites tested were detected.

Fluctuations in the quantitative secondary metabolite contents of the five selected medicinal plants from the oil exploration region in Nigeria were significant and could be attributed to environmental stressors such as carbon dioxide bump, which leads to a rise in temperature [10]. It has been reported that medicinal plants, in attempts to survive and resist the effects of this impact, develop hard leaf texture and produce much biomass to combat the environmental hazard [9]. This increase in the shoot of biomass could have led to significant increases in the yield of phytoconstituents, predominantly observed in *M. indica*, *M. oppositifolius*, *M. aboensis* and *N. laevis* in this study. Among this plant's biomass are the secondary metabolites that plants produce to protect themselves from environmental factors. To counteract the detrimental impacts of stress, these plants harvested from Ogoni synthesize an extensive number of secondary metabolites, such as phenolics, tannins, flavonoids and alkaloids, as observed in this case. Similar observations have been reported in *Vernonia amygdalina* and several species in Fabaceae, Arecaceae, Poaceae, Cyperaceae, Euphorbiaceae and Malvaceae families in the Niger Delta region of Nigeria [2].

The GC-MS analysis of plant extracts is a phytochemical fingerprinting technique developed for the identification of constituents and their relative abundance in the extract

matrix, metabolite profiling and impurities detection [13]. It provides detailed structural information that assists in compound identification despite its limited application for volatile and semi-volatile compounds and its dependency on available databases. The GC-MS technique has been successfully applied in the discovery of amphetamines, opiates, benzodiazepines and some designer drugs.

This study assessed the impact of oil exploration activities on the major phytochemical constituents of five important medicinal plants. The study identified 48 compounds with significant relative abundance in both the test and control samples. It was observed that all the samples and their respective controls contained different alkaloidal chemotypes. Except for *M. indica*, which contained two similar alkaloids - 1,3-diazocane-2-thione (T14/C7) and 5-methyl-1,2-oxazol-3-amine (T15/C6)- in both the test and control samples, all the other plant samples contained different alkaloids. It was, therefore, imperative to regard alkaloids as the fingerprint in this study. The quantification of alkaloids in the samples revealed high densities in the test samples of *F. exasperata* and *M. aboensis*, presenting the first insight into the effect of environmental stressors on alkaloids. A previous study reported that *Vernonia amygdalina* and *Ocimum gratissimum* from the oil exploration regions in Nigeria showed lesser phytochemical diversity and bioactivities than those obtained from non-oil exploration regions [2]. Compared with previous studies, *F. exasperata*, *M. oppositifolius* and *N. laevis* from Ogoni showed more diverse alkaloids than their respective controls, while both *M. aboensis* and *M. indica* contained 2 and 5 alkaloids each from both the test and controls, suggesting that the survival of these plants in the harsh environment may induce biosynthesis of new phytochemicals as a means of adaptation [2,17].

Limitations of this study

This study did not isolate or characterize these compounds and the study on the effect of the observed differences on the biological activities of these plants has not been concluded. However, T1/T2 and C1/C2 of *M. aboensis*, T3/C3 of *F. exasperata* and several other compounds identified in this study have been associated with antimicrobial and/or anticancer activities [18,19].

CONCLUSION

The study profiled the diversity and similarity of secondary metabolites in *Magnifera indica*, *Ficus*

exasperata, *Mallotus oppositifolius*, *Millettia aboensis* and *Newbouldia leavis* harvested from the crude oil exploration region (Ogoni) and crude oil exploration-free region (Awka). There are higher tannin and flavonoid contents in all the test samples than in the controls. The GC-MS analysis fingerprinted alkaloids in all the samples, with more diversity in the test samples, suggesting possible biotransformation, accumulation, or depletion by unfavourable environmental conditions caused by the multifactorial nature of crude oil exploration activities in Ogoni. These findings provide valuable insights into the alterations in phytoconstituents caused by crude oil exposure and the need for environmental conservation.

DECLARATIONS

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Conflict of interest

No conflict of interest is associated with this work.

Contribution of authors

We declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors. Conceptualisation and design; Uchenna Odoh, Christopher Ezugwu, Nonhlangabezo Mabuba and Charles Nnadi; Data collection and analysis: Eleje Okonta, Patience Ugwu, Esther Godwin, Vincent Chukwube and Edith Diovu; Drafting manuscript: Patience Ugwu, Edith Diovu, Vincent Chukwube and Charles Nnadi; Supervision: Uchenna Odoh, Christopher Ezugwu and Nonhlangabezo Mabuba. All authors read and approved the manuscript for publication.

Ethical approval

Not applicable.

Availability of data and materials

We indicate that the datasets used and analysed during the study are contained in this manuscript.

Use of Artificial intelligence/Large language models

We also declare that we did not use Generative artificial intelligence (AI) and AI-assisted technologies in writing the manuscript.

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