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Assessment of Physicochemical and Fungal Isolates in Crude Oil-Contaminated Soils in Ataba, Andoni, Rivers State, Nigeria

Olagbenro, B.A., Obire, O. and Aleruchi, O.
Department of Microbiology, Faculty of Science,
Rivers State University, Nkpolu-Oroworukwo,
P.M.B. 5080, Port Harcourt, Nigeria.
***Corresponding Author:** *olagbenro.bolaji@rsu.edu.ng*

ABSTRACT

Petroleum hydrocarbons enter the environment through oil spills, improper waste management, industrial effluent discharge, and other anthropogenic activities, resulting in ecological degradation. Crude oil contamination is a major environmental problem that adversely affects soil quality and microbial diversity. This study investigated the physicochemical and fungal populations associated with crude oil-contaminated soils in Ataba, Andoni, Rivers State, Nigeria. Seven soil samples were collected from different contaminated sites and analyzed using standard microbiological methods. Total heterotrophic fungi (THF) and hydrocarbon-utilizing fungi (HUF) were enumerated using the spread plate technique. Pure fungal cultures were isolated and characterized based on their cultural and microscopic features. The THF counts ranged from 3.3×10^4 to 6.5×10^5 CFU/g, while HUF counts ranged from 1.7×10^5 to 6.7×10^6 CFU/g. The fungal isolates identified included *Aspergillus niger*, *Aspergillus* spp., *Penicillium* spp., *Candida* spp., *Mucor* spp., *Blastomyces* spp., *Trichosporon* spp ., *Fusarium* spp., and *Rhizopus* spp. The physicochemical parameters were low in concentration across the sampling locations. The occurrence of hydrocarbon-utilizing fungi in the contaminated soils demonstrates their adaptation to petroleum-polluted environments and their ability to metabolize hydrocarbon compounds. The findings of this study indicate that crude oil-contaminated soils in Ataba harbor diverse fungal species with biodegradation potential. These indigenous fungi may serve as valuable candidates for bioremediation and the cleanup of crude oil-polluted environments. Their application could contribute to environmentally sustainable management of petroleum-contaminated sites.

Keywords: Soil, Crude oil, hydrocarbon-utilizing fungi, physicochemical, fungal population, Ataba.

Introduction

The proliferation of artisanal refining activities has exacerbated the environmental crisis in the Niger Delta. Artisanal refineries, popularly known as Kpo-fire or Gallon refineries, are rudimentary, small-scale operations that employ primitive distillation techniques to process stolen or locally sourced crude oil (Nwankwoala, 2022). These unregulated operations result in the indiscriminate discharge of untreated oil-polluted effluents and solid wastes into surrounding ecosystem. Indigenous microorganisms in hydrocarbon-polluted soils develop adaptive mechanisms to survive in these contaminated environments.

These fungi play a crucial role in the natural attenuation of pollutants, utilizing hydrocarbons as carbon and energy sources through enzymatic pathways (Chikere et al., 2023). Studies have demonstrated that hydrocarbon concentration in soil adversely impacts fungi diversity, creating a narrow fungal diversity dominated by hydrocarbon-tolerant species. The Andoni Local Government Area of Rivers State, particularly the Ataba community, is a hotspot for artisanal crude oil refining activities. The intense, unregulated operations in this area have led to severe soil contamination, with visible impacted points including oil-stained soil, sludge deposits, charred ground surfaces, and surface water in nearby creeks showing visible oil sheen.

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The pollution is attributable to illegal artisanal refining operations, with evidence including crude oil discharge points, refining residue pits, and burnt drums.

Therefore this study investigated the physicochemical and fungi population in crude oil contaminated soil in Ataba, Andoni Local Government Area (LGA) in Rivers State, Nigeria.

Materials and Methods

Study Area

The study was conducted in Ataba Community, Andoni Local Government Area, Rivers State, Nigeria. Ataba is a coastal community situated within the Niger Delta region and is characterized by mangrove vegetation, intertidal creeks, and low-lying swampy terrain, which is typical features of the Niger Delta environment (Nwankwoala, 2022).

The community is located approximately between latitudes 4°30'N and 4°45'N and longitudes 7°10'E and 7°25'E as shown in Figure 1 (Kadafa, 2012).

Sample Collection

Soil samples were collected from the selected sampling sites SS1, SS4, SS6, SS7, SS10.SS12, SSC within Ataba Community**.**

At each sampling site, soil samples were collected at a depth of 0.5m, 1.0m and 2.0m using a sterile stainless-steel soil auger (Chikere et al., 2020). These sampling depths was selected because it represents the zone microbial activity and the region where hydrocarbon contamination is most concentrated following surface oil spills (Okoro et al., 2020). Soil samples were collected from multiple points within each sampling site and composited to form a consortium.

Approximately 500g of soil was collected from each sampling point and transferred into sterile, properly labelled polyethylene bags (Chikere et al., 2020). The collected samples were transported to the laboratory in ice-cooled containers to preserve the integrity of the microbial community and to prevent the overgrowth of specific microorganisms during transportation (Okoro et al., 2020). Upon arrival at the laboratory, the samples were stored at 4°C for a maximum period of 24 hours prior to analysis (Chikere et al., 2020).

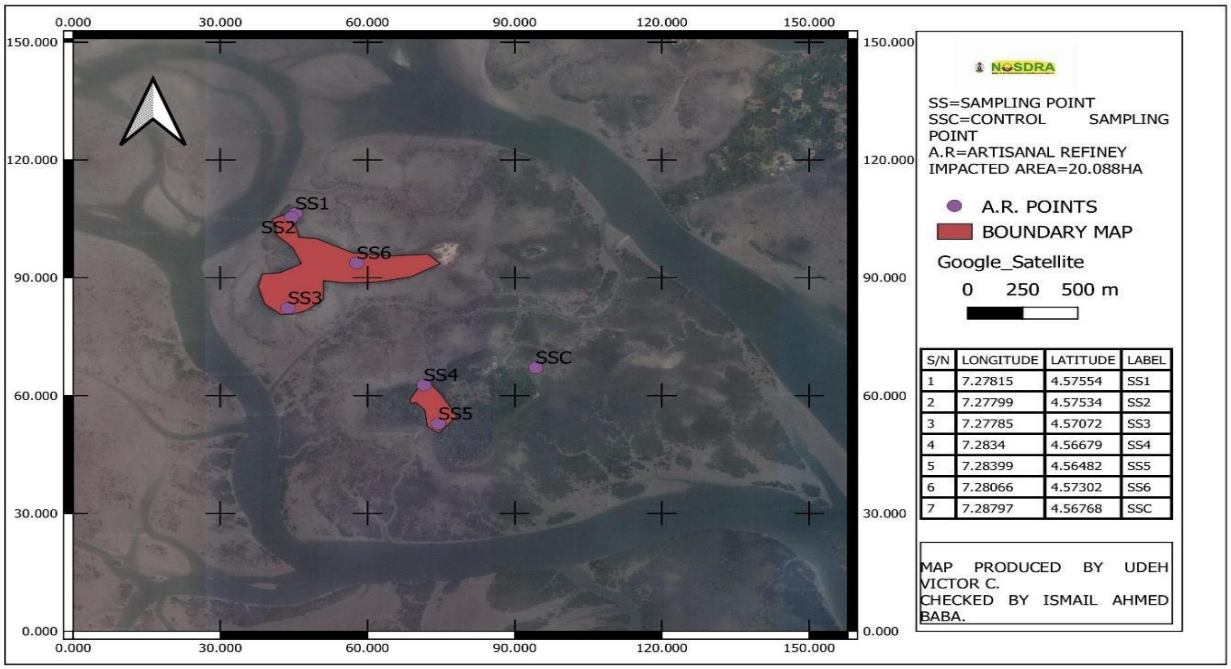


Figure 1: Study Area Showing Sampling Points in Ataba, Andoni LGA, Rivers State

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Microbiological Analysis

Determination of fungal population

The total fungi count was carried out using the spread plate technique. A ten-fold serial dilution was carried out by measuring 1g of soil sample into nine (9) mL of distilled water in a test tube covered with cotton wool and foil and mixed properly to make a dilution of 10^3. This was used to complete the ten-fold serial dilution. Exactly 0.1 mL aliquot of each diluent was introduced into sterile Petri dishes containing the Potato Dextrose Agar (PDA) for total fungi and Bushnell Hass agar for hydrocarbon utilizing fungi. The cultured plates were incubated at ambient temperatures (24 – 32 °C) for 3-5 days. The physiological characteristics of the colonies and their number which developed on the culture plates were used as basis for the counting, taking into consideration their dilution number. Counts were made from the plates containing 30-300 colonies. The isolates were aseptically sub-cultured into fresh potato dextrose agar, after counting and incubated at a temperature of (24 – 32 °C) for 3-5 days to obtain pure cultures of the isolates.

Isolation of fungi isolates

Discrete colonies obtained from the different agar were counted using the colony counter and recorded appropriately; the colonies were sub-cultured onto potato dextrose agar. The Cultured Petri dishes were placed in an inverted position in the incubator at a temperature of (24 – 32 °C) for 3-5 days to obtain pure cultures. Presumptive morphological identification of the colonies was done by observing their appearance on the media. The colonies were stored in agar slant for cultural/microscopic identification and characterization using fungi atlas by Barnett & Hunter (1998).

Physiochemical Parameters of the crude oil contaminated soil

These were carried out using the method described by Mohammed et al. (2013); APHA, (2017).

Determination of Soil pH and Temperature

Soil pH was determined using a digital pH meter **(**Jenway 3510, UK**)** following the method described by Okoro et al. (2020)**.**

A 10g portion of each soil sample was mixed with 25 mL of distilled water and agitated for 30 minutes. Thereafter, the pH of the resulting supernatant was measured after calibrating the pH meter with standard buffer solutions of pH 4.0, 7.0, and 10.0.

Soil temperature was measured *in situ* using a portable digital thermometer inserted into the soil at a depth of 10 cm (Chikere et al., 2020).

Determination of Moisture Content

Soil moisture content was determined using the gravimetric method by drying fresh soil samples in an oven at 105°C for 24 hours until a constant weight was obtained (Okoro et al., 2020). The percentage moisture content was calculated as the proportion of water lost relative to the initial wet weight of each soil sample (Chikere et al., 2020).

Determination of Total Organic Carbon and Soil Organic Matter

Total Organic Carbon (TOC) was determined using the Walkley–Black dichromate oxidation method. Soil Organic Matter (SOM) was subsequently calculated by multiplying the TOC value by the standard conversion factor of 1.724 (Okoro et al., 2020).

Determination Total Nitrogen

Total nitrogen was determined using the Kjeldahl digestion method (Okoro et al. (2020). Soil samples were digested with concentrated sulphuric acid in the presence of a catalyst, after which the resulting ammonium was distilled and titrated with a standard acid solution (Okoro et al., 2020).

Determination Available Phosphorus and Potassium

Available phosphorus was determined using the Bray-1 extraction method and the phosphorus concentration was measured using a spectrophotometer (Okoro et al., 2020).

Available potassium was extracted using ammonium acetate and subsequently determined using a flame photometer (Chikere et al., 2020).

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Determination of Heavy Metal Concentration

Heavy metal concentrations such as lead (Pd), cadmium (Cd), chromium (Cr), zinc (Zn), nickel (Ni), phosphorous (p) and magnesium (Mg) were monitored according to the method employed. 10g of air-dried soil sample was mixed with 0.2M nitric acid solution for 60 minutes in a digestion flask under high temperature of about 800^{O}C. The digest was then filtered through a filter paper and the volume made up to 100 mL by adding distilled water. The filtrates were analyzed using the atomic absorption spectrophotometer (AAS) GBC 908PBMT, Australia (Chikere et al., 2020).

Statistical Analysis

All data generated was analyzed statistically by calculating the mean and comparing the mean value with the acceptable standards. Data collected were statistically analyzed using Statistical Package for Social Sciences (SPSS 20).

Results

Table 1 shows the heterotrophic fungal population and hydrocarbon utilizing fungi of the crude oil contaminated soil. The results revealed a total heterotrophic fungal population with range value of 3.3 $\times10^4$ to 6.5$\times10^5$ CFU/g. While hydrocarbon utilizing fungi counts ranged from 1.7$\times10^5$ to 6.7 $\times10^5$. SS10 had the highest counts in THF, followed by SS1 and SSC with the least counts.

For hydrocarbon utilizing fungi, SS7 had the highest counts in HUF, followed by SS4 and SS12 with the least counts.
A total of ten (10)fungi genera were identified. They include *Aspergillus, Candida, Penicillium, Fusarium, Rhizopus, Cryptococcus, Mucor, Trichoderma Trichosporon* and *Blastomyces* species as presented on Table 2.

The percentage occurrences of fungi isolate from crude oil contaminated soil samples are presented in Figure 2*: Aspergillus* (25.93%), *Candida* (18.52%), and the least was *Trichoderma, Mucor and Trichosporon (*4%).

Table 1: Fungi Population (x10^{3}CFU/g) of Soil Samples from Ataba

Sample Code	Total Heterotrophic Fungi (CFU/g)	Hydrocarbon Utilizing Fungi (CFU/g)
SS1	4.7×10^4	4.2×10^5
SS4	4.6×10^4	6.2×10^5
SS6	4.0×10^4	2.7×10^5
SS7	4.9×10^4	6.7×10^5
SS10	6.5×10^4	3.6×10^5
SS12	4.0×10^4	1.7×10^5
SSC	3.3×10^4	3.4×10^5

Results of the physicochemical parameters determined for the soil samples from Ataba revealed that the pH values of the soil samples ranged from 6.3 (SS6) to 7.0 (SS12), indicating slightly acidic to neutral conditions. The control site (SSC) had a pH of 6.8. Soil temperatures ranged from 26.5°C (SS6) to 27.8°C (SS12). Moisture content ranged from 17.6% (SS12) to 24.3% (SS6). Total nitrogen content ranged from 0.13% (SS6) to 0.29% (SS12). Available phosphorus ranged from 9.52 mg/kg (SS6) to 18.43 mg/kg (SS12). Available potassium ranged from 106 mg/kg (SS6) to 136 mg/kg (SS12). Total organic carbon ranged from 1.95% (SS6) to 2.64% (SS12), while soil organic matter ranged from 3.36% (SS6) to 4.51% (SS12). The highest nitrogen content was recorded at SS12 (0.29%), followed by SSC (0.27%), while SS6 had the lowest nitrogen content (0.13%). Phosphorus and potassium followed a simi3lar trend, with SS12 showing the highest values (18.43 mg/kg and 136 mg/kg, respectively) and SS6 showing the lowest values (9.52 mg/kg and 106 mg/kg, respectively).

The control site (SSC) showed higher nutrient levels compared to most contaminated sites, the highest TOC (2.64%) and SOM (4.51%) were recorded at SS12, while the lowest TOC (1.95%) and SOM (3.36%) were observed at SS6. The control site (SSC) recorded TOC and SOM values of 2.51% and 4.28%, respectively. Overall, TOC and SOM followed similar trends across the sampling sites, with relatively higher values observed at SS12 and the control site compared to the other locations.

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Table 2: Macroscopic and Microscopic Characteristics of Fungal Isolates from the soil sample

Isolate Code	Colony Colour	Texture	Form (Shape)	Reverse Color	Fungi Microscopy	Suspected Organisms
SSCE	Blue green dark green	Velvety powdery tan	Mold	Yellowish white to tan	Septate hyphae: brush like Penicillium nature	***Penicillium* sp**
SS12C	Smokey green/yellowish green	Granular rugose rapid	Mold	White to pale yellowish back	Septate hyphae unbranched vesicles phialides	***Aspergillus* sp**
SS1A	Cream /light brown	Smooth-paste like moderate	Yeast (oval)	Pale cream	Oval budding cells, pseudo hyphae	***Candida* sp**
SS7D	White with light basic violet	Cottony woolly rapid	Mold	Light pink to deep violet	Septate hyphae sickle shaped macro conidia	***Fusarium* sp**
SS10B	Gray black	Fluffy cottony lifter aggressive	Mold	White to pale grey	Broad non septate hyphae dark rhizoids	***Rhizopus* sp**
SS1B	Cream brown	Fluffy cottony aggressive	Mold	White to pale brown	Broad & non hyphae lacks rhizoids	***Mucor* sp**
SSCC	Cream to yellowish white	Moist wrinkled moderate	Yeast (rectangular)	Pale yellow cream	True hyphae break into arthroconidia	***Trichosporon* sp**
SS4E	Cream to yellowish viscous	Lightly mucoid moderate (round)	Yeast	Pale cream-tan	Round budding yeast cells thick capsule	***Cryptococcus* sp**
SS6B	White	Wrinkled white mucoid edge	Mold	Pale cream	Capsule round budding yeast cells surrounded by distant clear halo with distinct visible show capsule no true hyphae	***Blastomyces* sp**
SS1D	bright green to deep blue as margin/ring	fluffy or woolly form flat patches	Mold	Pale light yellow or amber	septate hyphae with highly branched conidiophores. flask shaped phialides at the angle bearing clusters of small green round conidia at their tips	***Trichoderma* sp**

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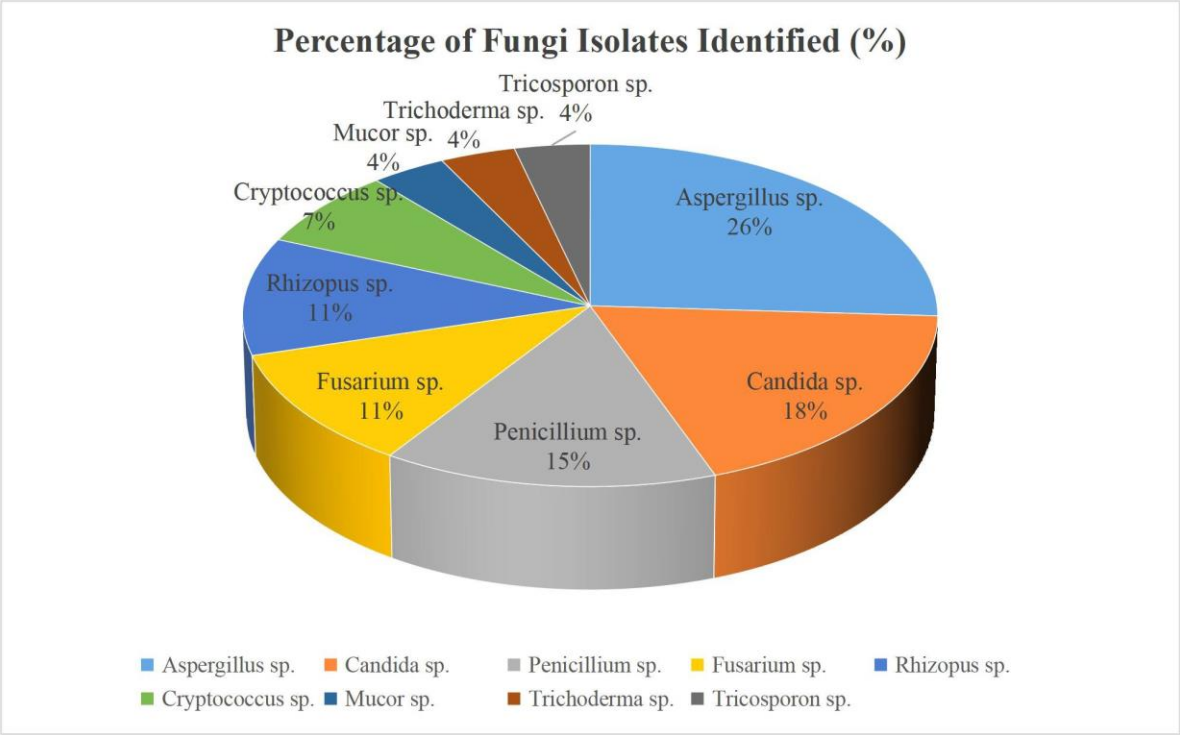


Figure 2: The percentage (%) occurrence of fungi isolated from crude oil contaminated soil

The lead (Pb) concentrations in soil samples from the seven sampling sites, the results showed that lead was not detected in any of the soil samples, with all concentrations falling below the detection limit of the instrument. The nickel (Ni) concentrations in soil samples showed that nickel was only detected in the control site (SSC) at a concentration of 1.55 mg/kg. The cadmium (Cd) concentrations from the seven sampling sites showed that cadmium was detected only in SS1(0.15 mg/kg) And SSC with 0.05mg/kg in the soil samples. Zinc was the most abundant heavy metal detected across all sampling sites, with concentrations ranging from 12.14 mg/kg (SS1) to 25.84 mg/kg (SSC). The highest zinc concentration was recorded at the control site (SSC, 25.84 mg/kg), followed by SS12 (25.50mg/kg) and SS7 (15.76mg/kg). The lowest zinc concentration was observed at SS1 (12.14mg/kg, Manganese (Mn) concentrations in soil samples from the seven sampling sites results showed that manganese concentrations ranged from 0.25 mg/kg (SS6) to 9.15 mg/kg (SS12). The highest manganese concentration was recorded at SS12 (9.15 mg/kg), followed by SSC (8.70 mg/kg) and SS7 (6.35 mg/kg).

The cobalt (Co) concentrations in soil samples from the seven sampling sites showed that cobalt was detected in five sampling sites: SS4 (0.40 mg/kg), SS7 (1.15 mg/kg), SS10 (3.25 mg/kg), SS12 (1.55 mg/kg), and SSC (1.35 mg/kg). The highest cobalt concentration was recorded at SS10 (3.25 mg/kg), while SS4 had the lowest detectable concentration (0.40 mg/kg). The copper (Cu) concentrations in soil samples from the seven sampling sites results showed that copper was only detected in SS7 at a concentration of 0.75 mg/kg.

The chromium (Cr) concentrations in soil samples from the seven sampling sites results showed that chromium was only detected in SS4 at a concentration of 0.75 mg/kg. Iron (Fe) concentrations in soil samples from the seven sampling sites results showed concentrations ranging from 12.14 mg/kg (SS1) to 25.84 mg/kg (SSC).

The highest iron concentration was recorded at the control site (SSC, 25.84 mg/kg), followed by SS12 (25.50 mg/kg) and SS7 (15.76 mg/kg) as presented on Table 3.

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Table 3: Physicochemical Properties of Soil Samples from Ataba

Parameter	SS1	SS4	SS6	SS7	SS10	SS12	Control (SSC)
pH	6.5	6.7	6.3	6.6	6.4	7.0	6.8
Temperature (°C)	26.8	27.0	26.5	27.2	26.9	27.8	27.5
Moisture (%)	22.1	20.5	24.3	21.8	23.6	17.6	18.4
Nitrogen (%)	0.15	0.18	0.13	0.17	0.14	0.29	0.27
Phosphorus (mg/kg)	10.83	11.61	9.52	10.94	9.91	18.43	15.21
Potassium (mg/kg)	113	118	106	116	109	136	129
TOC (%)	2.10	2.25	1.95	2.18	2.02	2.64	2.51
SOM (%)	3.62	3.88	3.36	3.76	3.48	4.51	4.28
TPH (mg/kg)	19,617.37	12,586.66	23.2	12,291.32	7,160.24	12,753.45	22,307.93
PAH(ppm)	1.41	9.55	0.99	1.43	1.15	0.79	0.88
Lead (Pb) (mg/kg)	-	-	-	-	-	-	-
Nickel (Ni) (mg/kg)	-	-	6.90	-	-	-	1.55
Cadmium (Cd) (mg/kg)	0.15	0.00	0.00	0.05	-	-	0.05
Zinc (Zn) (mg/kg)	12.14	13.02	15.50	15.76	13.94	25.50	25.84
Manganese (Mn) mg/kg)	2.25	2.20	0.25	6.35	1.80	9.15	8.70
Cobalt (CO) (mg/kg)	-	0.40	-	1.15	3.25	1.55	1.35
Copper (CU) (mg/kg)	-	-	-	0.75	-	-	-
Chromium (Cr) (mg/kg)	-	0.75	-	-	-	-	-
Iron (Fe) (mg/kg)	12.14	13.02	15.50	15.76	13.94	25.50	25.84

Discussion

The fungal counts obtained at this site, suggests that hydrocarbon contamination promotes fungal growth (Mohanram & Kumar, 2019). Fungi are known to be more tolerant than bacteria to high hydrocarbon concentrations and can degrade recalcitrant hydrocarbons such as PAHs (Mohanram & Kumar, 2019). The control site (SSC) had relatively high fungal counts, indicating the presence of a diverse fungal community in the unpolluted environment (Mohanram & Kumar, 2019). The presence of *Aspergillus, Penicillium, Fusarium*, and *Rhizopus* in the contaminated soils supports the role of fungi in hydrocarbon degradation (Samson et al., 2019). The fungal counts observed in this study are within the range reported for hydrocarbon-contaminated soils in the Niger Delta by Chukwura et al. (2016)

The hydrocarbon utilizing fungi (HUF) results demonstrated the presence of fungi capable of utilizing petroleum hydrocarbons in the soil samples. The occurrence of HUF indicates that the contaminated soils contain fungal populations that may contribute to the natural attenuation of petroleum hydrocarbons. Fungi such as *Aspergillus, Penicillium, Fusarium* and *Candida* have previously been associated with hydrocarbon-contaminated environments and possess enzymatic systems capable of degrading complex hydrocarbon compounds (Mohanram & Kumar, 2019; Chikere et al., 2020). The presence of HUF in the study area therefore suggests that indigenous fungi may contribute to the biodegradation and natural attenuation of petroleum hydrocarbons (Mohanram & Kumar, 2019; Okoro et al., 2020).

The predominance of *Aspergillus* and *Penicillium* is consistent with previous studies on hydrocarbon-polluted environments (Mohanram & Kumar, 2019; Samson et al., 2019). *Aspergillus* species are known for their ability to tolerate high hydrocarbon concentrations and degrade complex hydrocarbons such as PAHs (Mohanram & Kumar, 2019).

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The presence of *Candida* species in the contaminated soils is consistent with previous studies reporting yeast species in crude oil-contaminated soils (Obire et al., 2021). The presence of *Cryptococcus* species is of public health concern, as this genus includes clinically important pathogens such as *Cryptococcus neoformans* (Madigan et al., 2019). The isolation of fungal species (figure 1) such as *Aspergillus niger*, *Trichoderma* spp, *Fusarium* spp, *Mucor* spp and *Penicillium* spp from soil contaminated sites in Ataba, Andoni highlights the adaptability and ecological roles of fungi in polluted environments**.**

These organisms have earlier been reported as hydrocarbon bio-degraders by April et al., (2015). The fungi play a vital role in the bioremediation of oil-contaminated soils (Mukherjee et al., 2021). *Aspergillus niger* is a well-known filamentous fungus capable of degrading hydrocarbons due to its production of extracellular enzymes such as lipases and peroxidases, which facilitate the breakdown of complex organic pollutants. Its presence in the oil-contaminated soils aligns with previous findings that *Aspergillus niger* can utilize hydrocarbons as a carbon and energy source (Chaudhry et al., 2022). The findings is also in conformity with the report of Akpoveta et al. (2021) who revealed the isolation of *Trichoderma* spp., *Penicillium* spp., *Rhizopus* spp., *Fusarium* spp., and *Aspergillus* spp, from crude oil polluted soil at Agbor area of Niger Delta. Similar to the result of Mbachu and Chukura (2016) were a total of 8 fungal isolates; *Candida tropicalis*, *Rhodosporidium toruloides, fusarium oxysporium, Aspergillus clavatus, Saccharomyces cerevisiae, Candida albicans, Microsporium gypseum* and *Trichophyton Mentagrophytes*. The isolation of these fungi from oil-contaminated soils at Ataba, Andoni that these organisms are not only surviving but potentially contributing to the natural attenuation of pollutants. The predominance of *Aspergillus* spp (figure 2) across various sites followed by species of *Candida* species, P*enicillium* species, F*usarium* and *Rhizopus* species respectively aligns with existing literature on fungal distribution in diverse environments. This finding corresponds favourably with the work of Chukwura et al. (2016) who reported *Aspergillus* spp and *Penicillium* spp displaying the highest extent of degradation in selected workshops in Akwa Ibom mechanic sites.

Presence of *Aspergillus* spp in various sites might be due to its prolific spore production, dispersal capabilities and its cosmopolitan nature. The presence of these fungi in the soil samples is an indication that these isolates were able to survive in the crude oil contaminated environment while those that could not survive in the crude oil contaminated soil were eliminated due to unfavourable conditions caused by the crude oil. Moreover, one plausible explanation for this resilience is its ability to produce extracellular enzymes such as lipases, esterases, and peroxidases which can degrade hydrocarbons into simpler, less toxic compounds (Zheng and Yan, 2018).

The physicochemical parameters such as pH, moisture content, temperature, nitrogen, phosphorus, potassium, total carbon content, soil organic matter, zinc, manganese, cobalt, lead, nickel, cadmium, chromium, iron and polycyclic aromatic hydrocarbon in this study were in a favourable range that supports the bioactivity of fungi. this is in line with the work of Sabah et al., (2016) who showed these parameters contribute to their biodegradable potential. This is similar with the result obtained by Idowu and Ijah, (2018) who showed the pH range of crude oil contaminated soil to be 5.01 to 6.49. the high pH values for all the soil assessed in this research, agrees with the findings of Orjiakor et al. (2019) who showed the pH value of crude oil effluents to be between 6.3 to 7.8. Temperature from all the sites ranges from lower temperature of 26.5^{o}C to highest temperature of 27.8^{o}C. This is in concordance with the work of Sabah et al. (2016) who showed the temperature of treated refinery effluents to be between 25.2 and 25.3^{o}C at Kaduna refinery. Moisture content of all soil samples in this study ranges between 24.3 to 17.6 %. This is agreeing with the result obtained by Idowu and Ijah, (2018) who showed the moisture content of crude oil contaminated soil to be 17.4 and 21.14 % in Eleme, Rivers State, Nigeria. The absence of lead in the soil samples is noteworthy, as this metal is often associated with crude oil contamination (Ogundele et al., 2020), the low nickel concentration This suggests that artisanal refining activities in the study area may not be significant sources of nickel contamination (Okoro et al., 2020). The absence of cadmium in the soil samples is consistent with findings from other studies on artisanal refinery-impacted soils (Ogundele et al., 2020).

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The elevated zinc concentrations at SS12 and SS7 correlate with the high TPH concentrations at these sites, suggesting a possible association between hydrocarbon contamination and zinc accumulation (Ogundele et al., 2020; Nwankwoala, 2022), The high manganese concentrations at SS12 and SS7 correspond with the high TPH levels at these sites, supporting the co-occurrence of hydrocarbon and heavy metal contamination in artisanal refinery-impacted soils (Aniefiok & Ekpo, 2024), These values are lower than those reported for unpolluted soils, reflecting the impact of hydrocarbon contamination on phosphorus availability (Chikere et al., 2020). The presence of heavy metals such as zinc, manganese, and cobalt in the contaminated soils has significant public health implications, as heavy metals can co-select for antibiotic resistance in environmental bacteria (Martínez et al., 2019; Iweriolor et al., 2026).

Conclusion

The study shows that soils within the crude oil contaminated soil are good sources of hydrocarbon-clastic fungi, notably *Aspergillus* spp, suggesting that the fungi specie possesses a high tolerance for hydrocarbon contaminated environments and also the physicochemical parameters were also in favor of the fungi. This study contributed to the database on locally available fungal population and their ecology. These microbes exhibited appreciable bioremediation potential for the clearing of crude oil polluted site in Ataba, Andoni. Zinc was the most abundant heavy metal detected followed by Iron, Lead, Cadmium Nickel, Copper, and Chromium were largely below detection. Hydrocarbon contamination within the study area demonstrates the environmental impact associated with petroleum-related activities (Okoro et al., 2020; Chikere et al., 2020). Further studies on its biodegradation ability could contribute to the development of ecofriendly strategies for restoring oil-contaminated soils.

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