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# Physico-chemical properties and mycoflora profile in some coastal wetlands of Akwa Ibom State, Nigeria: Potential challenges for agro-ecological and public health

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**Abstract**. *Toby AT, Bassey IN, Effiong ME, Iduseri EO, Enyiukwu DN, Osu SR. 2024. Physico-chemical properties and mycoflora profile in some coastal wetlands of Akwa Ibom State, Nigeria: Potential challenges for agro-ecological and public health. Intl J Bonorowo Wetlands 14: 9-18.* This study assessed physico-chemical properties as it affects the distribution and diversity of mycoflora in different wetlands (Ibeno, Itu, Nsit-Ibom and Uyo) of Akwa Ibom State. The sediments and water samples were collected and cultured on Potato Dextrose Agar (PDA) and Sabouraud Dextrose Agar (SDA). Pure cultures of the mycotic isolates were identified using a molecular technique based on PCR amplification, sequencing of the internal transcribed spacer, and phylogenic analysis. At the same time, the physico-chemical properties of the specimens were determined using standard analytical methods. The results of the physico-chemical analysis showed that temperature and pH ranged from 27.27±0.33-29.21±003ºC and 5.17±009-7.30±0.17 respectively per samples per locations. The presence of Cr, Cd, Pb, Mn, Zn, Fe, Ca, nitrates, sulfates, phosphates, vanadium, suspended solids, and dissolved solids amongst other variables were detected in the water bodies, thus indicating possible agro-anthropogenic pollution. The results also showed that *Candida tropicalis, Aspergillus niger, A. terreus, A. aculeatus, A. tamarii, Penicillium citrinum, P. rolsfi, A. flavus, A. nominus* and *Trametes polyzona* were associated with the wetlands. The most commonly isolated fungi from the four locations were species of the genera *Aspergillus*. For the sediment, Nsit Ibom was dominated by *T. polyzona* (60%) while Ibeno was dominated by *C. tropicalis* (40%), *Aspergillus* and *P. citrinum* dominated Nsit Ibom (60%) and Uyo (60%) for water samples respectively. The fungal isolates showed differential affinity and adaptation to the ecosystem's heavy metals, ions and physical properties. Recent medical evidence, however, has associated these mycotic species with life threatening health conditions in both immuno-competent and immuno-compromized individuals and, as such, pose a serious menace to agro-ecological and public health. Therefore, this study lends credence to mycoflora diversity to aquatic habitat quality and as well provides baseline information that could spur conservation and proper management of the wetlands.

**Keywords:** Coastal sediments, myco-contaminants, mycoflora, public health, water quality

## INTRODUCTION

Wetlands are ecosystems where the water table is near the edaphic surface or where water covers the surface of the land either perennially or temporarily at certain times of the year. They usually occur along sea, river and stream shorelines, or on lowlands and valley bases (Ekong and Akpan 2014). Wetlands portend extensive food webs and biodiversity (Mitsch and Gosselink 1993; Cummings and Klugs 2000; Pittock et al. 2015; Edo and Albrecht 2021); contributing to timber, medicinal plants, fish, shellfish, arable and paddy crop production (Dapa and Brown 2020; Abraham et al. 2021). Wetlands function as ecological kidneys, and play vital roles in controlling flood intensity and frequency, abating erosion, and improving water quality (Dapa and Brown 2020; Balwan and Kour 2021).

Fungi of the divisions Zygomycota, Basidiomycota, and Ascomycota; and the genera *Fusarium, Alternaria, Trichoderma, Cladosporium, Cryptococcus, Penicillium, Aspergillus, Rhizopus, Curvularia,* etc. have been isolated from shoreline sediments and water from different wetlands (Freed et al. 2019; Adedire et al. 2021). The number and types of mycotic organisms present in wetlands are thought to correlate with the water quality (Jan et al. 2014; Liu et al. 2015; Adedire et al. 2021).

Seasonal variations in environmental factors and anthropogenic activities profoundly affect wetland health (Chesteen 2012; Edo and Albrecht 2021). These factors interact in ways that affect relative abundance and substrate density in wetlands. Though Nigeria is richly endowed with wetlands along its Atlantic coast, the Niger Delta of Nigeria is regarded as the second most critically endangered wetland environment in Africa due to heavy metals and hydrocarbon contamination from crude oil exploration (Sidhoum et al. 2020). These fallouts could alter mycofloral density in wetlands (FAO 1994, 2007;

Ekong and Akpan 2014; Edo and Albrecht 2021; Enyiukwu et al. 2021).

In addition, intensive farming, deforestation, mining, and discharge of industrial sewage near shorelines are reported to spur ecological degradation; affecting the diversity and density of saprophytic decomposer fungi and quality of wetland waters (Ekong and Akpan 2014; Saturday 2015; Dapa and Brown 2020; Edo and Albrecht 2021). For instance, high carbon quality, phosphorus (P), temperature and total nutrient contents (N, K) correlated with high fungal growth, biomass accumulation and diversity in some polluted streams (Liu et al 2015). Conversely, high concentration of hydrogenium ions was reported to seriously decrease mycotic growth and diversity in some studied wetlands (Jan et al. 2014).

In Idah River, Nigeria, high presence of *Aspergillus*, *Fusarium*, *Penicillium* and *Trichoderma* species was directly proportional to high electrical conductivity, turbidity and concentration of sulfur and arsenic ions that emanated from suspended and dissolved solids in the River (Adedire et al. 2021). These genera of mycoflora have been variously implicated in fungi-induced diseases of field crops, and stored agro-products. Also, their mycotoxins harm fish and other aquatic fauna (Onuoha and Obika 2015; Oleveira and Vasconcelos 2020). The rising population of these fungal agents in wetlands portends potential danger to public health in the third world compounding widespread challenges of malnutrition and metabolic or pathogenic diseases especially in sub-Saharan Africa (Enyiukwu et al. 2018a, b, 2020). Lew et al. (2013) stated that mycological diversity and community compositions could be reliable indicators of wetland water quality and ecosystem health.

Therefore, this study generally sought to determine the impact of physico-chemical parameters of wetland environments on the diversity and distribution of mycoflora on coastal wetlands of Akwa Ibom State.

## MATERIALS AND METHODS

### Study area

This study was conducted in Akwa Ibom State, a major wetland farming State in southern Nigeria; located within geographic coordinates of latitudes 04°32´N and Longitudes 7°25´and 8°25´E. The State occupies a distinct and contiguous area of 8142 square km. Therefore, four wetlands mapped out in 4 Local Councils of Uyo, Itu, Ibeno, and Nsit Ibom (Figure 1) within the State were sampled. They were: (i) Ibeno wetland (latitude 04°32'27"N, longitude 008°00'12"E); (ii) Itu wetland falls within Eniong Creek segment of the Cross River (latitudes 05°13'14" and 05°19"N, and between longitudes 007°56'14" and 007°56'59"E); (iii) Nsit Ibom wetland (Latitude 4°53'0"N and longitude 7°54'0"E); (iv) Uyo wetland is located on (Latitude 5°02'31"N and longitude 7°56'11"E).

### Collection of wetland water and sediment samples

Samples of water and sediments were collected from the four wetlands (Ibeno, Nsit Ibom, Itu and Uyo) of Akwa Ibom State, Nigeria, using sterile bottles and Ziploc bags respectively. The bottles were dipped at different locations in each wetland, opened and corked under water to make them air-tight. Two sampling areas were randomly selected within each wetland, and two replicate sediment samples were collected along the bank of each wetland using sterile scapels. The samples were sealed in the Ziploc bags, bagged in brown envelops and immediately taken to the University.

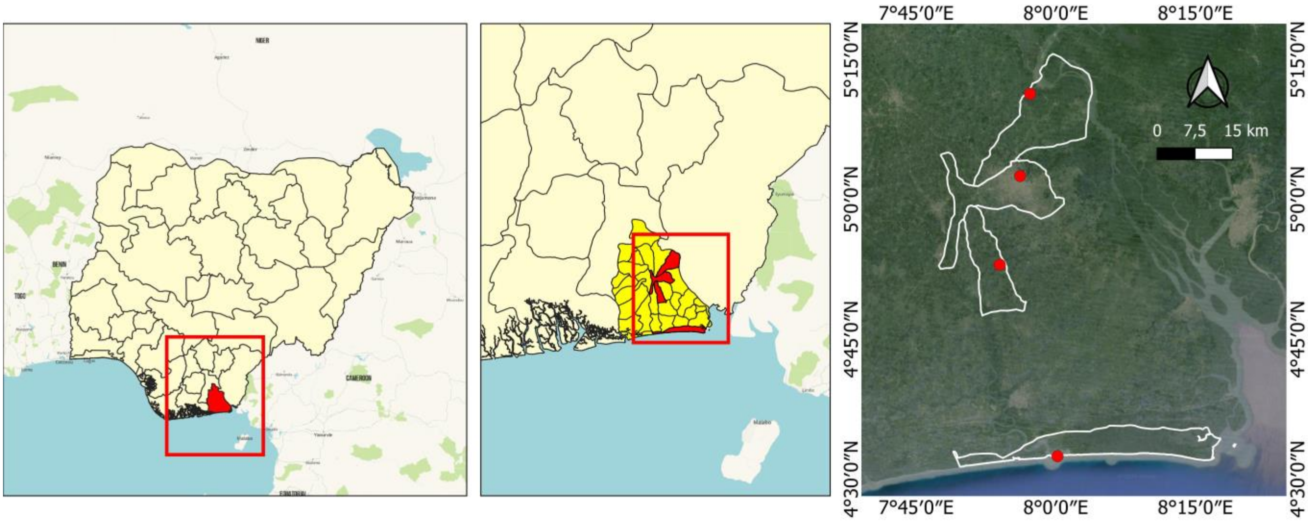


**Figure 1.** Map of Nigeria showing the study areas of Akwa Ibom State, Nigeria. Map of Akwa Ibom states showing the study council areas indicated by the 4 red dots

**Physico-chemical analysis of the water samples**

The water quality parameters including electrical conductivity and pH were determined using the conductivity meter and the pH meter respectively (Jan et al. 2014). Yoder (2022) described the standard classical qualitative methods used for testing for total hardness, calcium hardness, magnesium hardness, total solids, total suspended solids and total dissolved solids. The study examined the presence of ions of chlorine, sodium, iron, vanadium, chromium, cadmium, phosphate and sulfate ions in the water samples. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were done according to the protocol by APHA (1998).

**Determination of fungal diversity (using a culture-independent method), preparation of culture media and isolation of fungal species**

The isolation of fungal species and their diversity was conducted at the Botany and Ecological Studies Laboratory of the University of Uyo using the classical method as adopted by Atoyebi and Ekpo (2020) while the confirmatory molecular identification of the isolates was conducted at the Bioscience and Molecular Laboratory of the University of Nigeria, Nsukka, Enugu State, Nigeria.

**Preparation of culture media:** A conical flask was sterilized in an autoclave and placed on a sterile working bench. An electronic weighing balance was used to measure 10 g each of Potato Dextrose Agar (PDA) (Thermo Scientific Oxoid, UK) and Sabouraud Dextrose Agar (SDA) (Beena Infotech, India) respectively. Each of these quantities was separately poured into a 250 mL conical flask containing sterile distilled water and mixed properly with a stirring rod, then 0.2 mL of streptomycin (1.0 mg/mL) was introduced into each PDA and SDA media (to prevent bacteria growth), stoppered with a foiled non-absorbent cotton wool and autoclaved for 15 minutes at 15psi (Enyiukwu et al. 2021).

**Isolation of fungal species:** The isolation of fungal species associated with the wetlands was done using direct plating and serial dilution methods as adopted by Bello and Ukut (2015).

**Direct plating method:** Using a sterile syringe, about 1mL of the test sediment or wetland water sample was differently introduced into separate Petri dishes containing 10 mL of media (as prepared above) swirled gently to circulate and allowed to solidify. The Petri dishes were made air-tight with masking tape and incubated in the incubation chamber in the Laboratory at room temperature (27°C) and observed daily for 7 days.

**Serial dilution method:** Five test tubes ($10^1$-$10^4$) were prepared with 9 mL of distilled water. Next, 1 mL of water sample was pipetted into the first test tube and shaken to mix. From the first test tube, 1 mL was pipetted into the second, in that order to the fifth test tube. Then 1mL of serial dilution from $10^2$-$10^4$ was pipetted into the Petri dishes. The media were poured into the dishes, swirled gently to circulate and allowed to solidify. The Petri dishes were sealed with masking tape and kept in the incubator at room temperature (28°C). After 7 days, fungal growths were picked with sterile inoculation needle and sub-cultured repeatedly on fresh media to obtain pure cultures which were then maintained in stock McCartney bottles. A record of the types, colony characteristics and number of times each fungus was observed on the respective water or sediment specimens was taken.

**Molecular characterization of isolated mycoflora**

The genomic DNA of the test fungi was extracted from 3 day-old pure water and sediment cultures using hexadecyltrimethylammonium bromide (CTAB)-based method adopted from Hyde and Lee (1995), Nygren et al. (2008) and Debroas et al. (2017). DNA concentration was determined spectrophotometrically using Nanodrop (Model: Thermo Scientific, Wilmington, DE). PCR amplification of the highly conserved Fungal Internal Transcribed Spacer (ITS) region of the genomic DNA of the test fungi was done using primer pairs ITS1F and ITS4 as described in the studies of White et al. (1990). The amplicons were purified using ethanol sodium acetate precipitation protocol and sequenced (White et al. 1990).

**Statistical analysis**

This study hypothesized that the distribution of mycoflora is influenced by environmental parameters. For assessment of fungal diversity and evenness in different sediments and water, the Shannon diversity index (H'), Simpson's reciprocal index (1/D) and Pielou index (E) were calculated to represent the spatial diversity indices of mycoflora in each wetland. The Canonical Correspondence Analysis (CCA) ordination technique was used to test this hypothesis; an ordination technique assumes a unimodal distribution of species concerning environmental variables (Ukpong 1997). The fungal species, together with the corresponding wetland versus environmental variable data matrix were subjected to Canonical Correspondence Analysis (CCA) using PAST (Paleontological statistics) software version 3.0 (https://palaeo-electronica.org) to reveal the relationship between the fungal composition and environmental variables.

## RESULTS AND DISCUSSION

**Physico-chemical analysis of the test specimens**

The physical properties and presence of ions/chemical pollutants in the test water specimens from the 4 wetland habitats are presented in Table 1. It indicated the hydrogenium ions levels in the water samples ranged from 5.2 at Itu to 7.30 Nsit Ibom; Itu had the lowest temperature at 27°C, while Uyo recorded at 29.21°C was the highest. Salinity and hardness were highest at Ibeno while Nsit Ibom recorded the apex level of turbidity followed by Itu and Uyo in the water bodies tested. Uyo had very high electrical conductivity and total dissolved solids values. A slight presence of calcium, iron, copper, magnesium, potassium, nitrate and sulfate was detected in all the study’s water specimens from all the survey locations. Except for low values of vanadium (V) and lead (Pb) detected at Nsit Ibom and nickel (Ni) and chromium (Cr) at Uyo, all other locations surveyed in this study presented moderate levels of the test ions/radicals in all the water samples from all the test wetlands (Table 1).

**Characterization and identification of myco-isolates**

A total of 10 fungal isolates belonging to two divisions (Basidiomycota, Ascomycota), and 4 genera namely *Penicillium, Aspergillus, Trametes* and *Candida* were isolated from water and wetland specimens from Ibeno, Itu, Nsit Ibom and Uyo Local Government Areas of Akwa Ibom State (Figure 1). The distribution of fungi isolates in different wetland sediment and water were also captured in Figure 2. Nsit Ibom sediments was dominated by *A. terreus* (60%) and *A. niger* (30%); Ibeno by *C. tropicalis* (40%) and *T. polyzona* (30%); *A. flavus, T. polyzona* and *C. tropicalis* at 30% apiece were the dominant species in Itu sediment while Uyo sediment had *P. rolfsii* and *C tropicalis* at 40% each as prevailing species.

In Ibeno, the water specimen recorded 30% each of *P. citrinum, A. nominus,* and *T. polyzona,* and 20% apiece for *A. tamarii* and *A. terreus. A. flavus, A. nominus,* and *C. tropicalis* were observed at Itu water samples recording 50%, 30% and 20% respectively. Water specimen from Nsit Ibom had a high percentage presence of *A. flavus* (60%) and *C. tropicalis* (40%). Dominant species isolated in Uyo water specimens were *P. citrinum* (60%) and *A. nominus* (30%). However, *A. niger, A. aculeates, P. rolfsii, A. terreus,* on the one hand and *P. rolfsii, P. citrinum, A. tamarii, A. nominus* and *T. polyzona* were conspicuously absent in both water and sediment samples obtained from Itu and Nsit Ibom. Similarly, *T. polyzona, A. flavus* and *A. terreus* were not detected in samples from Uyo whereas *A. flavus* was not isolated from Ibeno specimens (Figure 2).

Table 2 shows the spatial distribution of fungi in water and sediment specimens from the 4 locations surveyed in this study. Nsit-Ibom recorded the highest index values for dominance for fungal species in water specimens (0.5200), followed closely by Uyo (0.4600), while Nsit Ibom with a 0.4600 index represents the highest dominance for sediment specimens. Concerning diversity, Simpson 1-D index values of the test specimens of water and sediment ranging (0.4800-0.7200) translated to low distribution diversity in and between fungal species in both habitats. The Shannon diversity index of the test specimens in the habitats showed that Ibeno water and sediments specimens recorded 1.4180 and 1.3660; followed by 1.0300 and 1.3140 respective components. High Simpson (1-D) (0.7400) and Shannon index values (1.3660) were obtained for Ibeno water specimens, translated to the highest strains on diversity in the habitat.

**Table 1.** Physical and chemical properties of water samples taken from the different study locations in Akwa Ibom State, Nigeria

| Parameters and Survey Locations | | | | |
|---|---|---|---|---|
| **Parameter** | **Ibeno** | **Itu** | **Nsit Ibom** | **Uyo** |
| pH | 6.52 | 5.24 | 7.30 | 6.90 |
| Temperature | 28.52 | 27.60 | 28.00 | 29.21 |
| Colour | +++ | ++ | ++ | + |
| Turbidity | + | + | ++++ | +++ |
| Salinity (Cl) | ++++ | ++ | + | ++ |
| Hardness | ++ | + | + | + |
| Electrical conductivity | + | ++ | +++ | ++++ |
| Dissolved oxygen (DO) | ++ | + | + | ++ |
| BOD | +++ | + | + | ++ |
| COD | +++ | ++ | + | +++ |
| Ca | ++ | ++ | ++ | ++ |
| K | + | + | + | + |
| Mg | +++ | ++ | ++ | ++ |
| THC | ++ | ++ | + | + |
| Phosphate | + | ++ | ++ | + |
| Sulfate | + | + | + | + |
| Nitrate | + | + | + | + |
| TDS | + | ++ | ++ | ++++ |
| TSS | + | + | + | + |
| Copper | + | + | + | + |
| Iron | + | + | + | + |
| Lead | ++ | + | - | + |
| Zinc | + | + | + | + |
| Cadmium | ++ | ++ | + | + |
| Chromium | + | + | + | - |
| Nickel | ++ | ++ | + | - |
| V | ++ | ++ | - | + |
| Na | +++ | ++ | + | ++ |
| Mn | ++ | ++ | + | ++ |

Note: +: slightly present, ++: moderately present, +++: heavily present, ++++: very heavily present. Ca (Calcium), Na (Sodium), E. conductivity (Electrical Conductivity) DO (Dissolved Oxygen) BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), K (Potassium), Mg (Magnesium), THC (Tetrahydrocannabinol), TDS (Total Dissolved Solid), TSS (Total Suspended Solid), Fe (Iron) Cr (Chromium), Mn (Manganese), and V (vanadium).

**Table 2.** Spatial diversity indices of fungi species in wetland sediment and water sample in some Council Areas of Akwa Ibom State, Nigeria

| **Parameter** | Parameters, Locations and Specimens | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Sediment** | | | | **Water** | | | |
| | **Uyo** | **Itu** | **Nsit Ibom** | **Ibeno** | **Uyo** | **Itu** | **Nsit Ibom** | **Ibeno** |
| Dominance_D | 0.3400 | 0.2800 | 0.4600 | 0 2800 | 0.4600 | 0.3800 | 0.5200 | 0.2600 |
| Simpson_1-D | 0.6600 | 0.7200 | 0.5400 | 0.7200 | 0.5400 | 0.6200 | 0.4800 | 0.7400 |
| Shannon_H | 1.1940 | 1.3140 | 0.8979 | 1.4180 | 0.8979 | 1.0300 | 0.6730 | 1.3660 |
| Evenness_e^H/S | 0.8247 | 0.9301 | 0.8182 | 0.8262 | 0.8182 | 0.9334 | 0.9801 | 0.9801 |
| Brillouin | 1.1290 | 1.2470 | 0.8535 | 1.3340 | 0.8535 | 0.9827 | 0.6479 | 1.2980 |
| Menhinick | 0.4000 | 0.4000 | 0.3000 | 0.5000 | 0.3000 | 0.3000 | 0.2000 | 0.4000 |
| Margalef | 0.6514 | 0.6514 | 0.4343 | 0.8686 | 0.4343 | 0.4343 | 0.2171 | 0.6514 |
| Equitability_J | 0.8610 | 0.9477 | 0.8173 | 0.8814 | 0.8173 | 0.9372 | 0.971 | 0.9855 |
| Fisher_alpha | 0.8342 | 0.8342 | 0.5823 | 1.1080 | 0.5823 | 0.5823 | 0.3542 | 0.8342 |
| Berger-Parker | 0.4000 | 0.3000 | 0.6000 | 0.4000 | 0.6000 | 0.5000 | 0.6000 | 0.3000 |
| Chao-1 | 4.0000 | 4.0000 | 3.0000 | 5.0000 | 3.0000 | 3.0000 | 2.0000 | 4.0000 |

**Table 3.** Eigenvalue for variables in Uyo, Council area, Nigeria

| Axis | Eigenvalue | Percentage |
|---|---|---|
| 1 | 0.069547 | 85.56 |
| 2 | 0.011736 | 14.44 |

**Table 4.** Eigenvalues for variables in Itu Local Government Area, Nigeria

| Axis | Eigenvalue | Percentage |
|---|---|---|
| 1 | 0.036579 | 74.51 |
| 2 | 0.012511 | 25.49 |

**Table 5.** Eigenvalue of variables for Ibeno Local Council Area, Nigeria

| Axis | Eigenvalue | Percentage |
|---|---|---|
| 1 | 0.017341 | 78.72 |
| 2 | 0.0043462 | 19.73 |
| 3 | 0.00034047 | 1.546 |

**Table 6.** Eigenvalue for Nsit Ibom, Nigeria

| Axis | Eigenvalue | Percentage |
|---|---|---|
| 1 | 0.031066 | 99.99 |
| 2 | 4.241E – 06 | 0.01365 |

**Canonical Correspondence Analysis (CCA)**

The CCA ordination of the relation between fungal community compositions and physico-chemical properties of water samples from Uyo, Itu, Ibeno and Nsit Ibom wetlands is presented in figures 3, 4, 5 and 6 respectively while Eigen values and percentage variances of the principal axis are presented in Tables 3, 4, 5, and 6. In this analysis, Axis 1 and 2 explained 100% of the correlation between the wetland water samples, physico-chemical properties and the fungal communities.

CCA bi-plots indicated that the wetland water physico-chemical variables remarkably influenced fungal communities. In the bi-plots (1, 2, 3, and 4), small thick circles represent the fungal species, while the arrow lines represent the physico-chemical variables (vectors) the species had an affinity for. The length of the arrows is proportional to the magnitude or intensity of charge owing to environmental variables, while the direction of the arrow shows their correlation with the axes. Longer arrows reflect strong effects on fungal communities' establishment and vice versa. Also, the distance of a named species from the vector line connotes its preference or affinity to the vector.

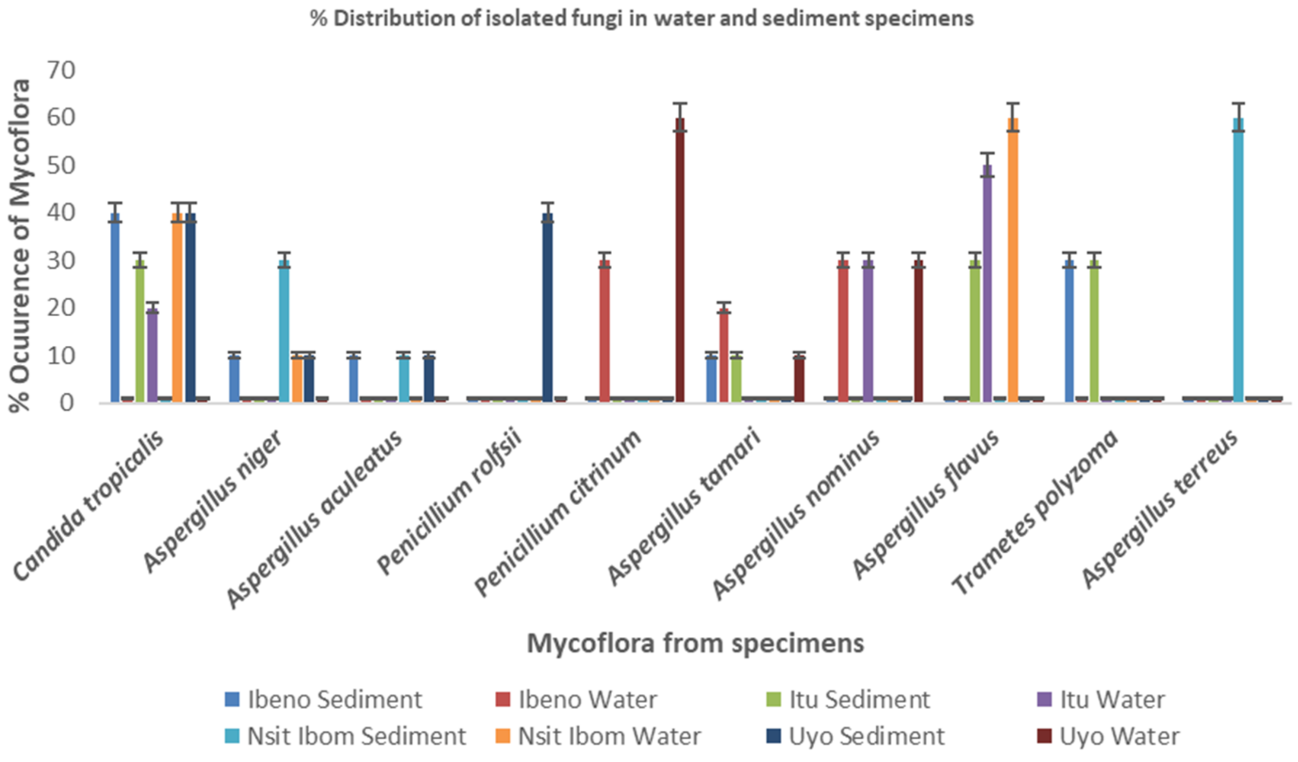


**Figure 2.** Percentage (%) distribution of fungi isolated from sediments and water samples in different wetlands of Akwa Ibom State, Nigeria

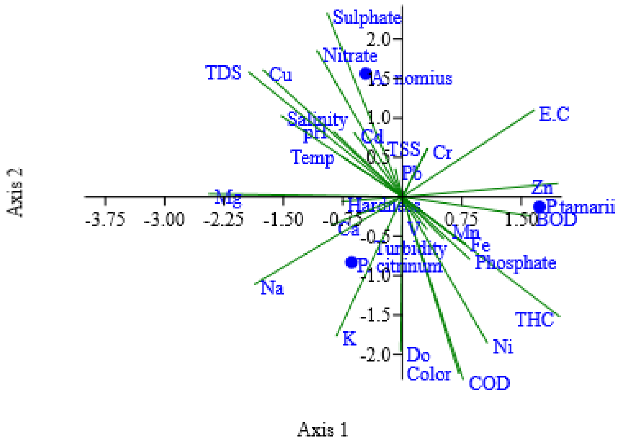


**Figure 3.** Canonical Correspondence Analysis (CCA) ordination for water samples from Uyo wetland, Nigeria

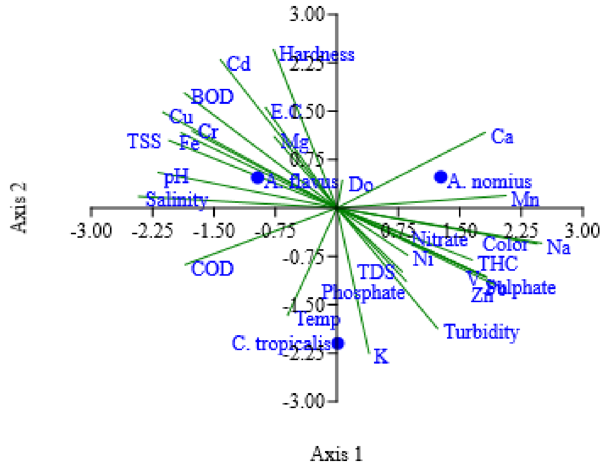


**Figure 4.** Canonical Correspondence Analysis (CCA) ordination for water samples from Itu wetland, Nigeria

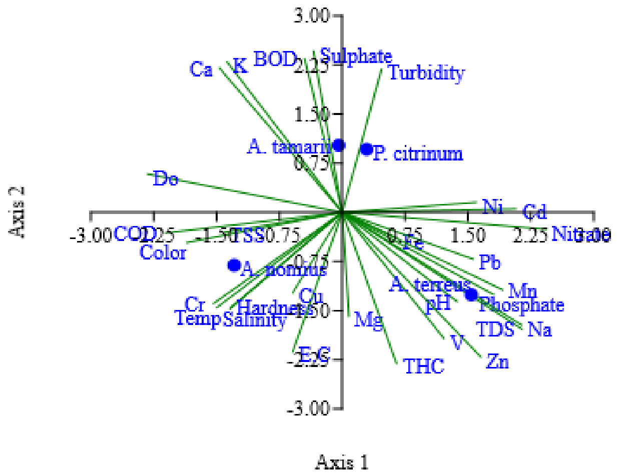


**Figure 5.** Canonical Correspondence Analysis (CCA) ordination for water samples from Ibeno wetland, Nigeria

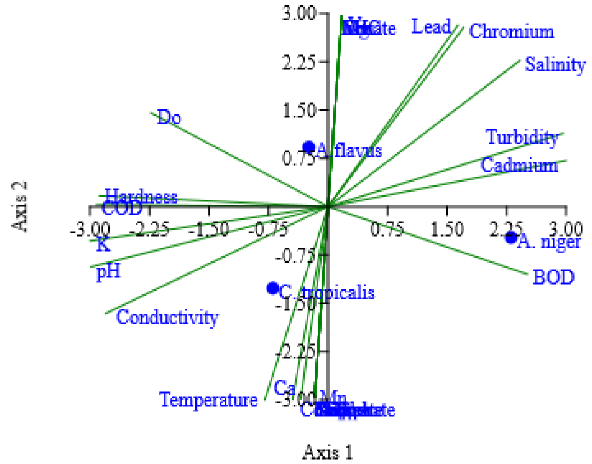


**Figure 6.** Canonical Correspondence Analysis (CCA) ordination for water samples from Nsit Ibom wetland, Nigeria

## Discussion

*Physico-chemical properties of the wetland specimens*

Several workers believe that temperature, pH, oxygen tension, dissolved organic matter, nitrates, phosphates and sulfates affect the fungal population. Temperature and hydrogenium potential profiles of wetlands are reported to encourage microbes' growth and decomposing activity. The fungal population increases with increasing temperature, while low pH causes the opposite in the growth and activity of mycoflora (Jan et al. 2014; Pietryczuk et al. 2018). Our data indicate that pH values are more or less neutral, and temperature range of 27-29°C is optimal for most aquatic bacteria and mycoflora, a view consistent with other workers (Atoyebi and Ekpo 2020). Turbidity is a measure of the clarity/cloudiness of a water body. It indicates the degree of presence of suspended solids in the water body. High turbidity promotes microbial growth and points to pollution. Our findings show high turbidity in Nsit Ibom and Uyo samples, conforming to the report of Adedire et al. (2021). However, it deviates from Bassey (2022) who noted turbidity ranges in Ikpa River far exceeding WHO recommendation.

Electrical conductivity denotes dissolved ions ($Cl^-$) in water and correlates salinity of the water body. Dissolved oxygen and organic matter influence diversity and activity of fungal species, especially litter decomposition in wetlands (Chesteen 2012; Pietryczuk et al. 2018). Low oxygen tension and organic matter in wetlands translates to poor growth and activity of aquatic mycoflora and vice versa. High and moderate presence or levels of organic matter, EC, salinity, nitrates, phosphates, sulfates point to rising agricultural and anthropogenic pollution in or around wetlands, consistent with Pietryczuk et al. (2018).

Moreover, except for vanadium, the presence of ions of Ca, Mn, Ni, Fe, Cu, Na, Cr, Cd and Mg detected in this study corroborated the reports of other investigators in the same locality and elsewhere (Ukpong and Peter 2012; Pietryczuk et al. 2018; Atoyebi and Ekpo 2020; Umana et al. 2022). Pb, Cr and Ni are used in many industrial processes such as making coins, electronics, batteries, stainless steel (Catainis et al. 2022). These heavy metals are highly soluble in water, and easily consumed by living organisms, they have been detected in the gills, liver and muscles of fish harvested from contaminated aquatic ecosystems, resulting in brain dysfunction and organs damage in mammals when ingested (Kunthia et al. 2020). Ca and Mg contribute to water hardness, and drinking or ingesting food from hard water could precipitate some forms of cardiovascular diseases (Oseji et al. 2019). Sulfates and phosphates are leachates washed into streams from rocks and artificial fertilizers on farmlands around shorelines. High phosphates and organic matter would translate to decreased oxygen tension in water bodies, which in turn is reported to encourage build-up of algae in water (Oseji et al. 2019).

*Mycotic profile and distribution*

Results obtained from this study showed that members of basidiomycota and ascomycota are the prevalent species in the wetlands. This is congruent with reports of several workers in fresh and marine ecosystems of temperate countries and the Himalayas, where members of the basidiomycetes and ascomycota such as species of *Penicillium, Verticillium, Fusarium,* and *Rhizopus* were the dominant mycotic organisms (Jan et al. 2014; Liu et al. 2015; Freed et al. 2019). This study's findings are also consistent with reports of other workers in Nigeria who found *Aspergillus* spp. *Penicillium* spp. *Candida* spp. *Fusarium* spp. and *T. polyzona* in Idah, Qua Iboe, and Cross Rivers (Bello and Ukut 2015; Okpashi et al. 2018; Bassey and Asamudo 2019; Atoyebi and Ekpo 2020; Adedire et al. 2021) as well as some common shellfishes harvested in estuaries in Local Councils of Akwa Ibom State (Bassey and Effiong 2016. The presence of *T. polyzona* a laccase-producing, dyestuff, and zenobiotic degrading basidiomycete is a sure indicator of anthropogenic and industrial (polyalliphatic hydrocarbons) pollution from within the shorelines (Ezike et al. 2020).

Several of the species in this study are potentially pathogenic. Pathogenic fungi occur and thrive well in polluted river waters (Pietryczuk et al. 2018). Several workers have reported that *Aspergillus* spp. *Penicillium* spp. *Rhizopus* spp. *Mucor* spp. *Alternaria*, and *C. tropicalis* attacked different species of fish and shellfish, causing infection and maceration of their eyes, head, gills, fins, liver and kidneys leading to sudden death (Jalees et al. 2012; Iqbal and Sajjad 2013; Iqbal and Saleemi 2013; Haridy et al. 2018; Adedire et al. 2021). Besides uses of stream-borne water for domestic chores, during dry spells, natives of the study area use them to irrigate their farms as such increasing the chances of crop disease outbreaks and storage losses due to water-borne phyto-fungal spores or propagules (Enyiukwu et al. 2020).

Consumption of food and vegetables contaminated with pathogenic fungi also could harm public health. Many fungi isolated in this study were implicated with human life-threatening infections in tropical locations. *T. polyzona* is associated with serious pulmonary infections (Gauthier et al. 2017), while *C. tropicalis* underscored invasive candidemia, arthritis, and meningitis (Kotharade et al. 2010; de Oliveira Santos et al. 2018; Haridy et al. 2018; Wang et al. 2021). The *Aspergillus* spp., and *Penicillium* spp. cause human localized and invasive *aspergillosis* and varied difficult respiratory and organ fungenamia in humans (Enyiukwu et al. 2020; Adedire et al. 2021). Infection of human tissues is wound requiring, or by ingestion of fungi-contaminated foodstuff; and could occur in immuno-competent or diabetes, HIV, organ transplanted, cancer or chemotherapy immuno-compromised individuals (Enyiukwu et al. 2018b; de Oliveira Santos et al. 2018).

The study showed that amongst the ten fungal isolates (*C. tropicalis*, *A. niger*, *A. terreus*, *A. aculeatus*, *A. tamarii*, *P. citrinum*, *P. rolsfi*, *A. flavus*, *A. nominus*, and *T. polyzona*), members of the genius *Aspergillus* was the most commonly encountered and dominant genus in the studied wetland ecosystems. This is consistent with the observations made by some researchers (Hyde and Lee 1995; Okpako et al. 2009; Bassey and Effiong 2016; Bassey and Asamudo 2019). It also revealed that physico-chemical factors strongly influenced the distribution patterns of the mycoflora in the wetlands. This finding affirms the report of Lew et al. (2013) that the diversity, composition and structural patterns of fungal communities are strongly influenced by amounts of dissolved nutrients and pollutants in a water body. Hence, the results suggest that wetland contamination suits pollution-tolerant genii and potentially pathogenic groups; this raises strong concern for human health and the functioning of wetland ecosystems**.** The relative abundance of different fungal species in both habitats (0.8182-0.9801) indicated similar and uneven distribution of species in the test specimens (Table 2). Differences in abundance and diversity of the test species could be ascribed to differences in the type and concentration of carbon sources, nitrogen and pollutants in the wetlands, a view strongly supported by Jan et al. (2014), Liu et al. (2015) and Adedire et al. (2021).

*Canonical Correspondence Analysis (CCA)*

The results of the affinities of the various myco-organisms with the physico-chemical properties of the test habitats are presented in Figures 3 to 6. The bi-plots of the figures indicate the relationships between particular mycoflora and their site preferences with physicochemical variables of the habitat. Generally, the CCA indicates that the primary and most influential environmental parameters affecting mycoflora growth and distribution in the test wetlands are pH, turbidity, temperature, hardness, salinity, nitrate, zinc, manganese, calcium, iron, TSS, BOD, sulfate, phosphate, chromium. The *A. nominus* exhibited high affinity for nitrate (Figure 3), Manganese and Calcium (Figure 4), hardness, chromium, temperature and salinity (Figure 6). The *C. tropicalis* exhibited a high affinity for temperature (Figures 4 and 6). *A. tamarii* showed higher preferences for BOD and sulfate (Figures 4 and 6). At the same time, the distribution of *P. Citrinum* was greatly influenced by turbidity (Figure 5). The *A. flavus* showed an affinity for nitrate (Figure 6), Iron and pH (Figure 4). *A. terreus* exhibited higher preference for phosphate, pH, manganese, sodium TDS (Figure 5). This study also revealed the genus *Aspergillus* have the highest contribution to microbial contamination in the aquatic ecosystems, a view eminently sustained by Gilna and Khaleel (2011), Parveen et al. (2013) and Sharif and Silva (2021). Generally, *Aspergillus* species are reported to be more tolerant to alkaline hydrogenium ions levels (pH), while *Penicillium* species appear more tolerant to acidic pH (Wheeler et al. 1991). The distribution of *A. terreus* in this evaluation was strongly influenced by pH (Figure 5), confirmed by Pardo et al. (2006).

Booth and Kenkel (1986) suggested that sea temperature was the single most important factor in the geographical distribution of marine fungi; this justifies the influence of temperature on the distribution of *C. tropicalis* (Figures 4 and 6). *Candida* species are more geographically likely to be found in sub-tropical and tropical climates where warm to high temperatures combined with humidity will likely enhance the adaptability of *C. tropicalis* (Chai et al. 2010). According to Pardo et al. (2006), most fungi use nitrate, which is reduced first to nitrite and then to ammonia; this justifies the affinity of *A. nominus* and *A. flavus* to nitrate in this study. Other major nutrients for fungi are sulfur, phosphorous, magnesium, and potassium which can be supplied to most fungi as salts. Nearly all fungi require trace elements like Iron, copper, manganese, and zinc as co-factors for enzymes (Pardo et al. 2006); this justifies the bonding of *A. terreus* to phosphate, manganese, and sodium, while *A. nominus* to manganese and calcium.

In conclusion, this study identified the fungal diversity associated with some wetlands in Akwa Ibom State belonging to the genera *Penicillium*, *Aspergillus*, *Trametes and Candida.* It also indicated the presence of several ions and, other physical variables and, that physico-chemical factors significantly influenced the type and distribution patterns of mycoflora in the aquatic ecosystem. The CCA revealed that the species of the isolated fungal genera exhibited differential affinities and adaptation to physical and chemical properties of the ecosystem, and these mycotic agents could serve as indicators for assessments of the health of water bodies.

### Recommendations

This study analysis revealed that the wetlands are being anthropogenically polluted which needs adequate measures to ameliorate the situation. It is therefore recommended that: (i) Deforestation and lumbering activities in and around wetland shorelines should be controlled by relevant governmental agencies. (ii) Disposal of domestic, organic and agricultural wastes by the natives into water bodies should be vehemently discouraged. (iii) Intensive agriculture involving the use of persistent broad-spectrum synthetic pesticides and other agro-chemicals including inorganic fertilizers whose residues and leachates (ions of ammonium, sulfates, phosphates, biphenyls etc.) pollute the aquatic food-web should be monitored and discouraged around shorelines. (iv) Mining for talc, clay and other solid minerals as well as rock quarrying activities along shorelines which result in large-scale debris/dusts being washed into wetlands, and leading to increased suspended and dissolved solids, turbidity, electrical conductivity and ions (phosphates, sulfates, arsenic, lead, copper etc.) levels in wetland waters, should be seriously controlled by relevant agencies. (v) Industrial effluents and discharges into wetlands and similar water bodies should be vigorously monitored and controlled to curtail polluting them with toxic chemical residues such as arsenic, mercury and lead with capacity to harm shellfish, fish and mammals. (vi) Adequate awareness programs should be implemented to sensitize the people/communities along shorelines on the dangers of wetland pollution, which portends harm to agro-ecological and public health. Such harms include low agricultural yields, toxic residue-contaminated agro-produce, mycotoxin contaminated sea-foods, poor air quality etc. Others are health conditions such as bronchitis, aspergillosis, allergies, pneumonia, fusariosis, persistent coughs, cancers etc. (vii) Campaigns to establish greenbelts with the capacity to remediate contaminants and sedimentation in wetland shorelines for improved environmental and public health should be encouraged and vigorously implemented by both governmental and non-governmental organizations.

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