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Role of Fungi in Environmental Mycoremediation for Sustainable Development in Kogi State

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Abstract

This study investigates the role of fungi in environmental mycoremediation for sustainable development in Kogi State. Through interviews and field surveys local fungal species present in contaminated sites and the ecosystem in general were identified and documented, systematic literature review, were carried out to assess the fungi mycoremediation capabilities, the respondents to the questionnaires were drawn from the three senatorial districts (Kogi East, Kogi West and Kogi Central) of Kogi State, Nigeria. One hundred and fifty (150) respondents were randomly selected from each senatorial district respectively making a total of Four hundred and fifty (450) respondents, the study explore the economic and environmental benefits of mycoremediation and addresses the challenges and limitations that may arise with the implementation of mycoremediation in the envinronment. Results showed that fungi play a significant role in the degradation of environmental pollutants, such as hydrocarbons, heavy metals, agro-wastes and pesticides. This process, known as mycoremediation, is a sustainable and eco-friendly method for cleaning up polluted environments. Fungi have the ability to break down and metabolize these pollutants, converting them into harmless substances. Through their mycelium, fungi can also absorb and store pollutants, preventing them from leaching into the surrounding environment. Additionally, fungi have been shown to improve soil quality and promote plant growth, making them a valuable tool for sustainable development. Overall, the findings of this study suggest that fungi have great potential in environmental mycoremediation and should be further explored for their role in achieving sustainable development in Kogi State.
Keywords: Mycoremediation, Bioremediation, Heavy Metal Remediation, Fungi, Environment, Sustainable Development.

Introduction

Nigeria's environment is heavily impacted with pollutants such as heavy metal contamination from industrial activities, oil spills by oil extraction activities and agricultural runoff from agricultural wastes, which have led to soil and water contamination and pollution has significant deleterious consequences for ecosystem. Additionally, agricultural practices often involve the use of chemical fertilizers and pesticides that contribute to soil degradation and water pollution. These environmental challenges not only threaten biodiversity but also impact food security, human health and livelihoods. Addressing these

issues is crucial for achieving sustainable development goals (SDGs) in Nigeria. The use of fungi to degrade or remove environmental pollutants, presents a promising avenue for sustainable development in Nigeria (Onwurah *et al.*, 2007; Osemwegie *et al.*, 2010). In Nigeria, there are reports of several practical applications of these indigenous fungi for mycoremediation of several environmental issues such as oil spill remediation, heavy metal absorption, soil remediation, agricultural waste management and water treatment (Onwurah *et al*., 2007; Itodo, 2011; Adenipekun and Lawal, 2012; Emmanuel *et al*., 2017; Adejumo and Adebiyi, 2020).
Mycoremediation is a bioremediation process that utilizes fungi to degrade or remove contaminants from the environment; it utilizes the natural abilities of fungi to break down complex organic pollutants including hydrocarbons, heavy metals, and pesticides into less harmful substances (Singh, 2006; Cotter, 2014; Sayan and Md.Salman, 2018). Mycoremediation when compared to traditional remediation methods can be an economical, eco-friendly, and effective strategy to combat the ever-increasing problem of soil and water pollution through detoxifying the environment and enhancing soil health by improving nutrient cycling and organic matter content (Bennet *et al.*, 2001; Osemwegie *et al*., 2002; Singh, 2006; Thomas *et al*., 2009; Ryan *et al*., 2019; Kulshrestha *et al*., 2014; Robert and Smith 2019; Akhtar and Mannan, 2020). Mushrooms possess specialized feeding habit with unique enzymatic capabilities that allow them to degrade a wide range of contaminants, including Agro-wastes, petroleum hydrocarbons, pesticides, and heavy metals (Okhuoya and Akpaja, 2005; Vaksmaa *et al*., 2023; Ogbeide and Henry, 2024). *Pleurotus species* were the most widely used mushrooms in the studies of bioremediation in Nigeria (Isikhuemhen *et al*., 2003, Adedokun and Ataga, 2006, Adenipekun and Lawal, 2012; Akhtar and Mannan, 2020). The innovative method of using mycoremediation as an effective method for addressing issues of pollution is now gaining attention, particularly in regions like Nigeria, where environmental degradation poses significant challenges to sustainable development (Akpasi, *et al*., 2023). Mycoremediation do not require extensive infrastructure or energy inputs; is often more economical and environmentally friendly than traditional remediation methods; it can also create new economic opportunities for local communities through jobs in mushroom farming or bioremediation services; foster community involvement and awareness regarding environmental issues thereby promoting sustainable practices among local populations in environmental restoration efforts; restore ecosystems more effectively; contributes to overall soil health by addressing pollution and promoting sustainable agricultural practices through improving its structure and fertility by the addition of organic matter from decomposed fungal biomass as such rehabilitate polluted sites, making them suitable for agriculture or natural habitats again potentially mitigating climate change impacts while restoring degraded lands (Boopathy, 2005; Labarere and Menini, 2000; Wasser 2007).
Kogi state is characterized by its rich biodiversity ranging from tropical forest to savanna, this biodiversity includes various fungal species that can be harnessed for mycoremediation

purposes. The people rely heavily on agriculture as a primary economic activity although there are other sources of livelihood including industrial activities, various environmental challenges, including soil degradation, water pollution from agricultural runoff due to heavy usage of chemical fertilizers and pesticides, reduced biodiversity and deforestation due to industrial activities contribute to the release of hazardous substances into the environment. These issues not only threaten local ecosystems but also impact the livelihoods of communities dependent on these resources.

Sustainable development in this context requires innovative approaches to environmental management, mycoremediation presents a sustainable solution for restoring contaminated lands as this technique has gained attention as an effective and sustainable method for addressing environmental contamination, particularly in areas affected by industrial activities, agricultural runoff, and urban pollution, the primary mechanisms through which mycoremediation operates include, Enzymatic degradation; Biodegradation; Biotransformation Bioaccumulation and Mycelial Networks. Research have shown that indigenous fungi can effectively decompose complex organic matter (pollutants) due to their co-evolution with the local flora and fauna, recycle nutrient and absorb heavy metals to improve soil health within ecosystems (D"Annible *et al*., 2006; Osagualekhor and Okhuoya, 2005; Thakur, 2014; Sayan and Md.Salman, 2018; González-González *et al*., 2022; Akpasi, *et al*., 2023; Vaksmaa *et al*., 2023). Identifying and cataloguing these fungal species is crucial for understanding their potential applications in environmental remediation.

Problem Statement

The people of Kogi state rely heavily on agriculture and industrial activities that release of hazardous substances into the environment, these brings about environmental challenges such as soil degradation, water pollution, reduced biodiversity and deforestation. These issues not only threaten local ecosystems but also impact the livelihoods of communities dependent on these resources. Identifying and cataloguing these fungal species is crucial for understanding their potential applications in environmental remediation.

Aim and Objectives

This study investigates the role of fungi in environmental mycoremediation for sustainable development in Kogi State.

- to identify and document various species of fungi found in our local environments
- to document the cultural or traditional usage of the identified fungi
- to find out if the people are aware of the mycoremediation tendencies of fungi

Materials and Methods

Through a comprehensive literature review, questionnaire and interviews with local farmers and community members, the potential of fungi in environmental mycoremediation were explored.

Sampling Procedure

The respondents to the questionnaires were drawn from the three senatorial districts (Kogi East, Kogi West and Kogi Central) of Kogi State, Nigeria. One hundred and fifty (150) respondents were randomly selected from each senatorial district respectively making a total of Four hundred and fifty (450) respondents; the respondents were interviewed by way of serving those questionnaires or interview for the non-educated respondents using questions on the questionnaires. The choice of selecting Kogi State was because the area consists of a lot of forest and savanna vegetation that supports fungal growth and in addition, the people had similar cultural and traditional beliefs.

Using a combination of ethnographic research and quantitative analysis the under listed questions were drawn to help the researcher have a focus:

1. Do they have knowledge about other fungi species apart from mushrooms?
2. What is People's Perception of other fungi that does not belong to mushrooms?
3. What is the awareness level regarding potentials of fungi role in mycoremediation?
4. What are the potentials of fungi role in mycoremediation?

Results

Table 1: Fungi species and their traditional importance in Kogi state

S/No	Botanical names	Common names	Group	Family	Traditionally known Importance
1.	*Acremonium recifei*	Orange rust	Rust	Hypocreaceae	Crop spoilage
2.	*Agaricus bisporus*	Table or button mushroom,	Mushroom	Agaricaceae	Food and
3.	*Amanita phalloides*	Death angel	Mushroom	Agaricaceae	Medicinal
4.	*Aspergillus flavus*	Ear rot	Mold	Trichocomaceae	Food spoilage Testing allergy, causes sinusitis,
5.	*Aspergillus niger*	Black mold	Mold	Trichocomaceae	Plant rot, Food spoilage
6.	*Auricularia auricular* Judae	Jew's ear, jelly ear	Mushroom	Auriculariaceae	Food and Medicinal
7.	*Bjerkandera adusta*	Smoky bracket	Mushroom	Meruliaceae	Medicinal
8.	*Calvatia fragilis*	Puffballs	Mushroom	Agaricaceae	Food and Medicinal
9.	*Cantharellus cibarius*	*Girolle*	Mushroom	Cantharellaceae	Food
10.	*Cephaleuros parasiticus*	Green scurf, red rust	Rust	Trentepohliaceae	Crop Spoilage

11.	*Chlorophyllum molybditis*	*False parasol*	Mushroom	Agaricaceae	Crop Spoilage
12.	*Claviceps africana*	Ergot	Mold	Calvicepitaceae	Crop Spoilage and Medicinal
13.	*Claviceps sorghi*	*Ergot*	Mold	Calvicepitaceae	Crop spoilage and Medicinal
14.	*Coprinopsis africana*	*Ink cap*	Mushroom	Agaricaceae	Medicinal
15.	*Coprinus picaceus*	*Ink cap*	Mushroom	Agaricaceae	Medicinal
16.	*Daldinia concentrica*	King Alfred's cake	Mushroom	Hypoxylaceae	Medicinal
17.	*Erysiphe spp*	Powdery mildew	Mildew	Erysiphaceae	Crop spoilage
18.	*Fomitiporia ellipsoidea /Phellenus ellipsoidea*		Mushroom	Hymenochaetaceae	Damage cut lumber
19.	*Fusarium graminearum*	Wilt	Mold	Nectriaceae	Destroy crops/plants
20.	*Fusarium oxysporium*	Panama disease	Mold	Nectriaceae	Destroy crops/plants
21.	*Ganoderma applanatum*	Bear bread	Mushroom	Ganodermataceae	Medicinal
22.	*Ganoderma lucidum*	Artist's bracket	Mushroom	Ganodermataceae	Medicinal
23.	*Ischnoderma resinosum*	Resinous polypore	Mushroom	Formitopsidaceae	Medicinal
24.	*Lactarius trivialis* Fr.,	Tacked milkcap	Mushroom	Russulaceae	Medicinal
25.	*Laetiporus sulpureus*	Chicken of the woods	Mushroom	Fomitopsidaceae	Medicinal
26.	*Lentinus squarrosulus, Lentinus subnudus*	Sawgill fungus	Mushroom	Polyporaceae	Medicinal
27.	*Microporellus dealbatus*	White polypore	Mushroom	Polyporaceae	Help in wood decaying
28.	*Mycosphaerella arachidis*	Leaf spot	Rust	Mycosphaerellaceae	Crop spoilage
29.	*Neurospora crassa*	Red bread mould	Mold	Sordariaceae	Food spoilage
30.	*Penicillium chrysogenum, Penicillium notatum*	Penicillin	Mold	Trichocomaceae	Damages buildings
31.	*Phanerochaete chrysosporium*	White rot	Mushroom	Phanerochetaceae	Decompose hard woods
32.	*Pleurotus tuberregium*	King tuber	Mushroom	Pleurotaceae	Food and Medicinal
33.	*Pleurotus ostreatus*	Oyster	Mushroom	Pleurotaceae	Food and Medicinal
34.	*Psathyrella corrugis*	Red edge brittlestem	Mushroom	Psathyrellaceae	decomposes hardwood, stumps and logs

35.	*Puccinia graminis*	Cereal rust	Rust	Pucciniaceae	Deformities in plants, growth retardation
36.	*Rhizopus stolonifer*	Black bread mould	Mold	Mucoraceae	Food spoilage
37.	*Saccharomyces cerevisiae*	Brewers' yeast	Yeast	Saccharomycetaceae	Brew alcohol from cereals
38.	*Schizophyllum commune*	Split gill	Mushroom	Schizophyllaceae	decomposes hardwood, stumps and logs
39.	*Sclerotinia sclerotiorum*	Cottony rot	Mold	Sclerotiniaceae	Plant disease
40.	*Termitomyces microcarpus*		Mushroom	Lyophyllaceae	Food and Medicinal
41.	*Trametes hirsuta*	Hairy turkey tail	Mushroom	Polyporaceae	decomposes hardwood, stumps and logs
42.	*Trametes versicolor*	Turkey tail	Mushroom	Polyporaceae	Medicinal
43.	*Trametes villosa*	turkey tail	Mushroom	Polyporaceae	Medicinal and decomposes hardwood, stumps and logs
44.	*Trichaptum abietinum*	Violet toothed polypore	Mushroom	Polyporaceae	decomposes hardwood, stumps and logs
45.	*Ustilago maydis*	*Corn smut*	Smut	Ustilaginaceae	Destroy crops and Medicinal
46.	*Volvariella volvacea*	Paddy straw	Mushroom	Pluteaceae	Food and Medicinal

Table 1 above shows different species of fungi identified in various communities of Kogi state, a total of 46 species of fungi where identified. These are grouped into mushrooms (29), molds (10), rusts (4), yeast (1), smuts (1) and mildew (1). Mushrooms had the highest number of species while yeast and smuts had the lowest and most of the identified species are used for either food or and medicinal purposes, very few were ignorantly identified in relation to mycoremediation functions.

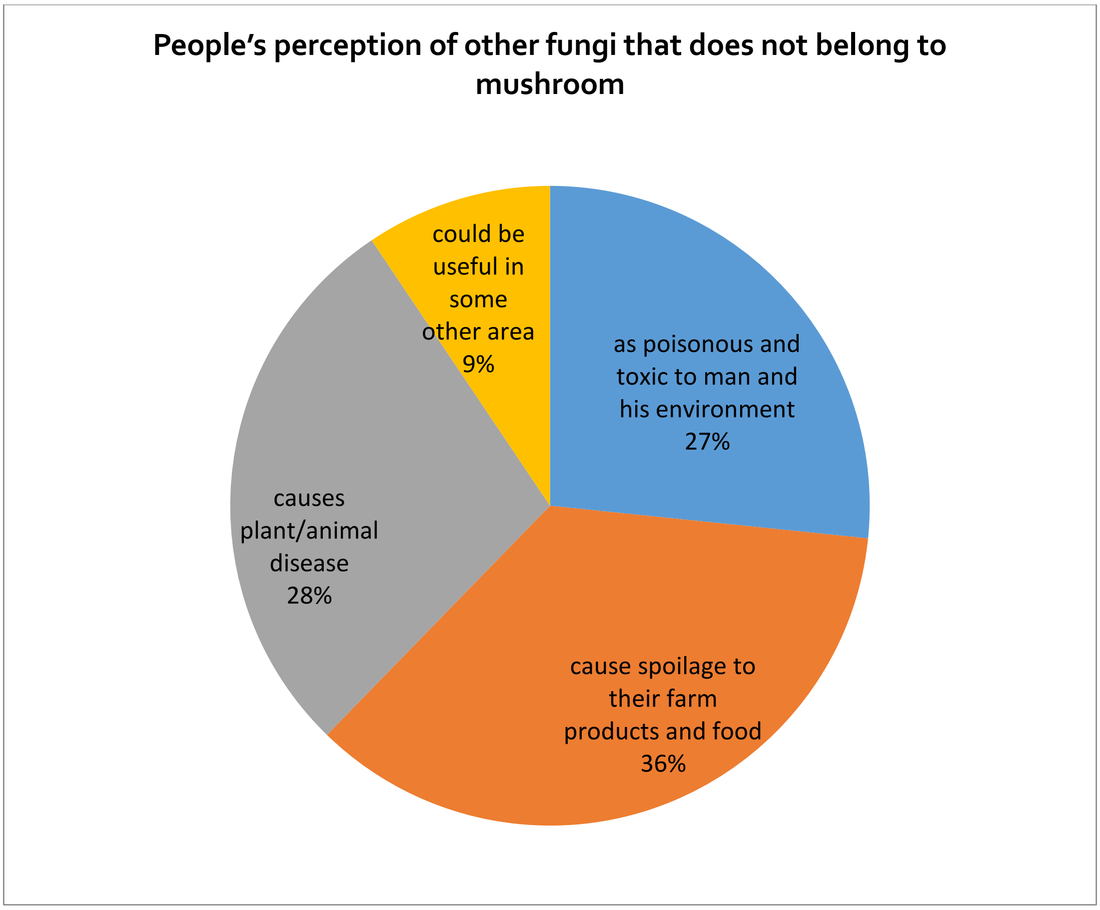

Fig 1: People's perception of other fungi that does not belong to mushroom

From various studies fungi have been utilized in ecosystem remediation to break down complex organic pollutants such as hydrocarbons, heavy metals, and pesticides into less harmful substances (Singh, 2006; Cotter, 2014; Sayan and Md.Salman, 2018). But the data collected as shown on Fig.1 above said otherwise; apart from edible mushroom and medicinal mushrooms all other group and species of fungi are almost useless to the society and that in fact they cause harm rather than good and as such should be destroyed or eliminated from the ecosystem. 68.7% of the respondents sees them as poisonous and toxic to man and his environment, 92% agreed that they cause spoilage to their farm products and food, while 73 % believed they causes plant/animal disease, only a few (24.3%) believed that they could be useful in some other area. It was discovered that the people are aware of the presence of fungi and that those that were not mushrooms are crop destroyers and disease-causing agents, some respondents did not believe that some of the fungi not in the mushroom group were living organisms.

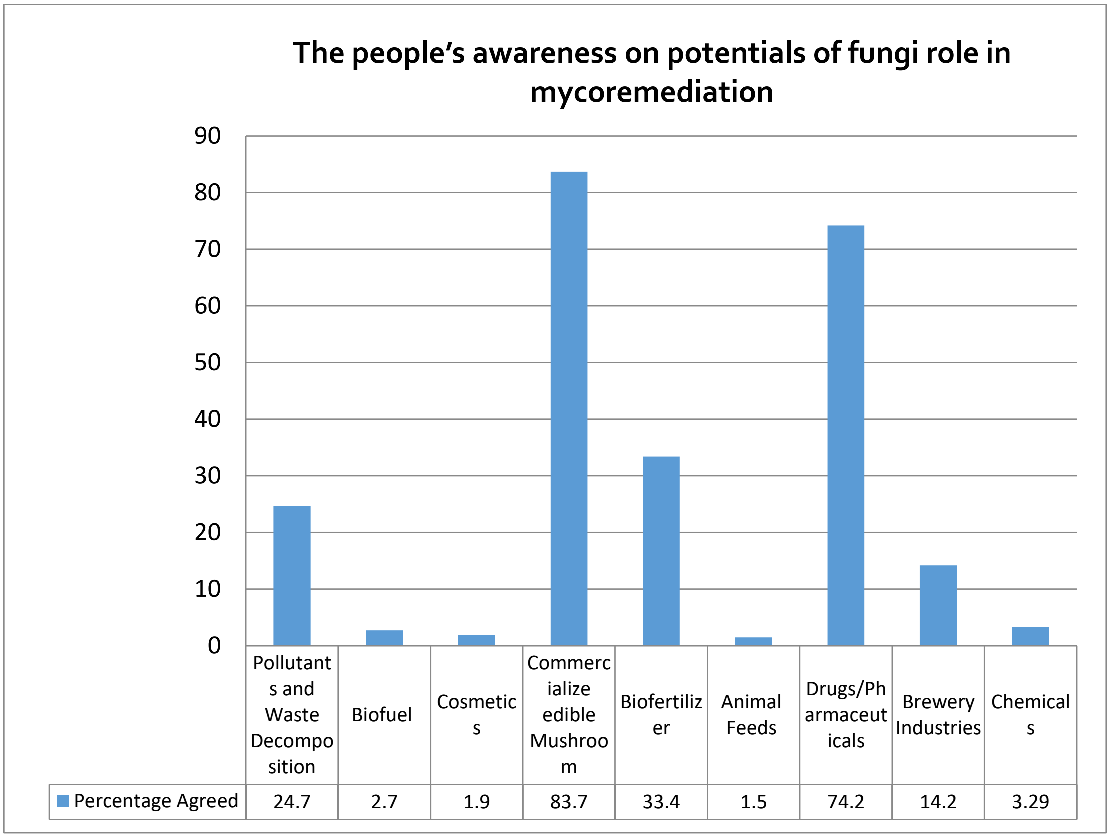

Fig 2: The people's awareness on potentials of fungi role in mycoremediation

Although there are reports of several practical applications of these indigenous fungi for mycoremediation of several environmental issues such as oil spill remediation, heavy metal absorption, soil remediation, agricultural waste management and water treatment (Onwurah *et al*., 2007; Itodo, 2011; Adenipekun and Lawal, 2012; Emmanuel *et al*., 2017; Adejumo and Adebiyi, 2020; Vaksmaa *et al*., 2023). In Kogi State the awareness of fungi potential in bioremediation is very low as shown in Fig. 2 above the people believed that apart from edible mushroom and those that serve medicinal purposes all other species of fungi are treat to human existence, this can be deduced from their percentage of agreement; Pollutants and Waste Decomposition (24.7%), Biofuel (2.7%), Biofertilizer (33.4%), Animal Feeds (1.5%), Drugs/Pharmaceuticals (74.2%), Brewery Industries (14.2%), Chemicals (3.29%), Cosmetics (1.9%), Commercialize edible Mushroom (83.7%) respectively.

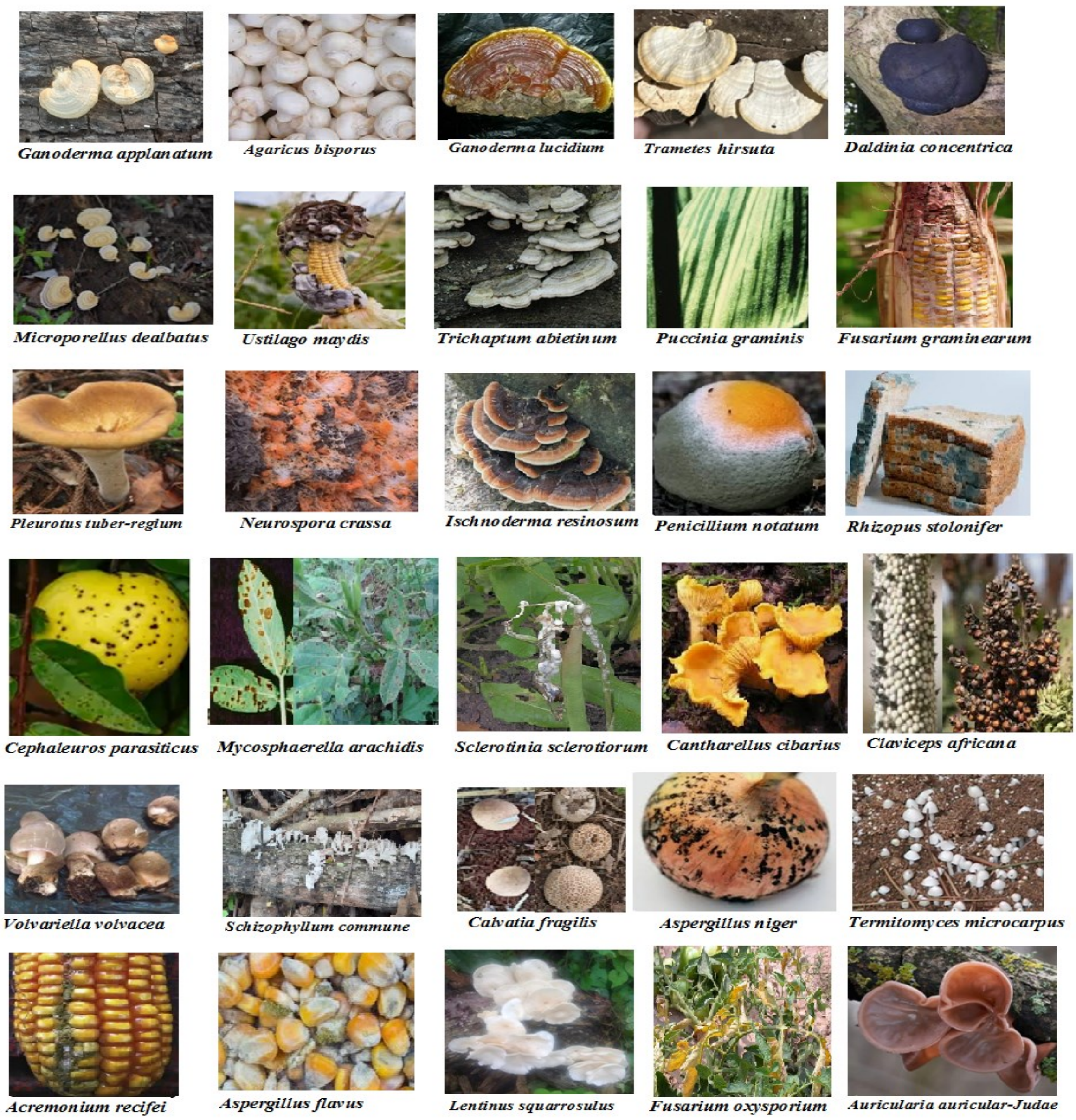

Plate 1: Photograph of some fungi identified in Kogi State

List of Fungi in Kogi state and their Potential Mycoremediation Activities

S/No	Fungi Species	Potential Mycoremediation Activities	References
1	*Acremonium recifei*	Anti bacterial drugs. play essential roles in nitrogen and carbon cycling and soil organic matter degradation, the most critical elements of soil ecology	Akpasi, *et al.*, (2023); Vaksmaa *et al.*, (2023)
2	*Agaricus* bisporus	Hyper-accumulation of heavy metals such as cadmium, copper, and zinc makes it essential for bioremediation through biosorption and also contain high levels of antibiotic properties.	Mishra and Srivastava (2020)
3	*Aspergillus niger*	Metabolize various organic pollutants, making it useful for the degradation of agricultural chemicals and industrial waste, produces enzymes antibiotics, citric acid which can be utilized for bioremediation through fermentation, biotransformation, biosorption of heavy metals like lead and cadmium from wastewater	Andersen *et al.*, (2011); Akpasi, *et al.*, (2023); Akhtar and Mannan, (2020); Mishra and Srivastava (2020); Ayilara *et al.*, (2023); Vaksmaa *et al.*, 2023)
4	*Aspergillus oryzea*	Production of enzymes antibiotics and citric acid which makes it useful in Fermentation for alcoholic beverages and waste management	Akhtar and Mannan, (2020); Ayilara *et al.*, (2023)
5	*Auricularia auricula*	Their ability to thrive more in sun exposure than other wood-decomposing mushrooms may make them useful for habitat renewal especially for devastated soil in arid, sunny ecosystems that are rich in lignicolous debris.	Adenipekun and Lawal, (2012)
6	*Bjerkandera adusta*	Degrade polycyclic aromatic hydrocarbons	Akhtar and Mannan, (2020) Akpasi *et al.*, (2023)
7	*Coprinus* species	Efficient hyperaccumulators of mercury, cadmium, and arsenic. Enzymes from this mushroom have been used as a dye remediation additive, and detergents for washing clothes. Living mycelium from this fungus also attacks nematodes.	Mishra and Srivastava, (2020)
8	*Fusarium oxysporum*	Degrading organic pollutants such as pesticides and herbicides, including dyes and other industrial waste products making it useful for remediating agricultural lands affected by chemical runoff	Akhtar and Mannan, (2020); Mishra and Srivastava, (2020) Ayilara *et al.*, (2023)
9	*Ganoderma applanatum*	The mycelium has very high tensile strength and an affinity for inhibiting and lysing bacterial cells, making it a good candidate for mycofiltration of water.	Vaksmaa *et al.*, (2023)

10	*Ganoderma lucidum*	It has ability to degrade lignin and cellulose can be used to degrade various organic pollutants and heavy metals such as polycyclic aromatic hydrocarbons (PAHs), making it useful in soil remediation. Its mycelium can bind heavy metals and may help in the remediation of contaminated water bodies	Goutam *et al.*, (2021); Vaksmaa *et al.*, (2023).
11	*Ischnoderma resinosum*	Biodegradation of synthetic dyes to substantial degree making them good candidates for mycofiltration units in textile operations and also for solid-state decolorization of clothing scraps.	Goutam *et al.*, (2021);
12	*Laetiporus sulpureus*	They are well known for their enzymatic activity in degrading a wide range of chemical dyes, making them good candidates for mycofiltration units in textile operations and also for solid-state decolorization of clothing scraps.	Vaksmaa *et al.*, (2023); Mishra and Srivastava (2020)
13	*Lentinula edodes*	It has shown promise in degrading certain types of environmental contaminants such as Heavy metals and organic pollutants while also enhancing soil quality through nutrient cycling	Akhtar and Mannan, (2020); Akpasi *et al.*, (2023)
14	*Microporellus dealbatus*	Help in hard wood decaying, decomposing organic matter essential for nutrient cycling in ecosystem, help enrich the soil and promote plant growth	Adenipekun and Lawal, (2012)
15	*Microporellus obovatus*	Help in hard wood decaying, decomposing organic matter essential for nutrient cycling in ecosystem, help enrich the soil and promote plant growth	Adenipekun and Lawal, (2012)
16	*Neurospora crassa*	Biodegradation of cellulose and other organic materials Cellulose-based waste Fermentation process cause humus, Biomass processing highly breaking down components of plant cells	Vaksmaa *et al.*, (2023)
17	*Penicillium chrysogenum, Penicillium notatum*	They are capable of degrading a variety of environmental pollutants, including some pharmaceuticals and pesticides, Production of antibiotics	Akpasi *et al.*, (2023); Ayilara *et al.*, (2023); Vaksmaa *et al.*, (2023)
18	*Penicillium decaturense*	Biodegradation of pesticides	Akpasi *et al.*, (2023); Ayilara *et al.*, (2023); Vaksmaa *et al.*, (2023)
19	*Phanerochaete chrysosporium*	Renowned for its lignin-degrading enzymes, is effective in the bioremediation of wood preservatives and other complex toxic organic pollutants, including dyes, chlorinated compounds	Adenipekun and Lawal, (2012); Akhtar and Mannan, (2020)

		and phenolic compounds, biodegradation of pesticides	
20	*Pleurotus tuberregium*	play an essential role in the bioremediation of organic contaminants	Wasser, (2007)
21	*Pleurotus ostreatus*	Has shown potential in the bioremediation of heavy metals (e.g., lead, cadmium) due to its extensive mycelial network. Degradation of lignin and cellulose for the remediation of oil-contaminated sites to break down pollutants (e.g petroleum hydrocarbons and pesticides) and agricultural waste and contaminated soil.	Adenipekun and Lawal, (2012); Akhtar and Mannan, (2020); Akpasi, *et al.*, (2023)
22	*Psathyrella corrugis*	Decomposes hardwood, stumps and logs	
23	*Rhizopus stolonifer*	Biosorption capabilities for heavy metals Heavy metals (e.g., zinc, copper)	Akpasi *et al.*, (2023)
24	*Rhizopus oryzae*	Degrade starches and sugars, which can help in treating wastewater containing organic materials, it can also assist in the breakdown of certain organic contaminants in soil	Akpasi *et al.*, (2023)
25	*Sclerotinia sclerotiorum*	Bioremediation of agricultural waste and contaminants Pesticides, herbicides	Wasser, (2007)
26	*Termitomyces letestui*	Biodegradation of pharmaceuticals and personal care products.	Adenipekun and Lawal, (2012)
27	*Tramates hirstura*	Decomposes hardwood, stumps and logs	Akpasi *et al.*, (2023)
28	*Trametes flavida*	Decomposes hardwood, stumps and logs	Ayilara *et al.*, (2023)
29	*Trametes versicolor*	Have ability to break down lignin to remediate a variety of persistent environmental pollutants or toxic compounds, including phenols and polycyclic aromatic hydrocarbons (PAHs) and pesticides. can be used to degrade synthetic dyes	Adenipekun and Lawal, (2012); Akhtar and Mannan, (2020) Akpasi *et al.*, (2023); Ayilara *et al.*, (2023); Vaksmaa *et al.*, (2023)
30	*Trametes villosa*	Eco-friendly detoxification of hazardous dye, Degrade aromatic polymers, Production of wine, Biodegradation of pesticides, Biodegradation of pharmaceuticals and personal care products	Akpasi *et al.*, (2023); Ayilara *et al.*, (2023)
31	*Trichaptum abietinum*	Decomposes hardwood, stumps and logs	Wasser, (2007)
32	*Schizophyllum commune*	Decomposes hardwood, stumps and logs	Adenipekun and Lawal, (2012)
33	*Volvariella volvacea*	Biodegradation of pesticides	Mishra and Srivastava, (2020)

The table above summarizes various fungi species found in Kogi State that have various capabilities which could make them suitable candidates for mycoremediation activities which is an innovative approach that utilizes fungi to clean up contaminated environments.

Each species listed has specific capabilities in targeting different types of pollutants, ranging from heavy metals to organic compounds. These fungi have been identified based on their indigenous presence in Kogi State and their documented capabilities in mycoremediation activities.

The identified activities of fungi found in Kogi state can be summarized as: possessing enzymes that allows lignin Degradation enabling them to degrade wood-based materials as well as certain environmental pollutants; Heavy Metal Absorption abilities from contaminated soils through their mycelial networks, effectively reducing metal toxicity levels; possessing abilities to Breakdown Organic Pollutant including hydrocarbons from oil spills, synthetic dyes from textile industries, and pesticides from agricultural runoff; consisting of Biosorption Mechanisms such as adsorption onto their cell walls or intracellular accumulation to sequester harmful substances from their environment. The use of these fungi not only aids in cleaning up contaminated environments but also promotes sustainable practices by utilizing natural biological processes rather than chemical treatments. The effectiveness of these fungi in mycoremediation depends on several factors including environmental conditions (pH, temperature), the nature of the contaminants present, and the specific metabolic pathways employed by each fungal species.

Way Forward

While mycoremediation holds great potential for sustainable development in Kogi State, several challenges must be addressed to implement mycoremediation effectively in Kogi State:

- More research is needed to identify suitable indigenous fungal species with effective bioremediation capabilities suited for specific contaminants prevalent in the local environment. Initiate small-scale pilot projects to demonstrate the effectiveness of mycoremediation techniques on contaminated sites within the region.
- There may be limited understanding among local communities about the benefits and methods of mycoremediation. There is a need for increased awareness about the benefits of mycoremediation among policymakers, local communities and other stakeholders as this is crucial for its successful implementation.
- Establishing clear supportive regulations governing the use of bioremediation techniques will be essential for ensuring safe and effective implementation. Establish monitoring protocols to assess the effectiveness of mycoremediation efforts over time.
- Adequate funding must be allocated to support research initiatives and field trials aimed at optimizing mycoremediation strategies.
- Government policies should encourage research funding and support initiatives that integrate mycoremediation into national environmental management strategies. Collaborate with academic institutions, NGOs, and government agencies to secure funding and technical support for mycoremediation initiatives. Train local farmers and

community members on mycoremediation practices so they can actively participate in remediation efforts.

By integrating these strategies into sustainable development plans for Kogi state, it is possible to address environmental challenges while promoting ecological balance and community well-being.

Conclusion

The exploration natural capabilities of indigenous fungi to remediate contaminated environments in Kogi State to enhance the overall ecosystem health presents a promising avenue for addressing environmental contamination or pollution through mycoremediation techniques towards restoring its ecological balance and ensuring a healthier environment and fostering economic resilience through environmentally friendly practices for future generations while promoting sustainable development goals. Its integration into local environmental management strategies could lead to improved land use practices and foster economic growth while preserving the region's natural resources. Further research is needed to identify specific strains prevalent in the region and evaluate their efficacy under local conditions.

Conflict of Interest

The authors declare that no conflict of interest could have influenced the work. This work is original research and has not been published or submitted for publication elsewhere.

References

Adedokun, O. M. and Ataga, A. E. (2006). Effect of crude oil and oil products on growth of some edible mushrooms. *Journal of Applied Science and Environmental Management* 10(2), 91-93.

Adejumo I. O. and Adebiyi O. A. (2020). Agricultural solid wastes: Causes, effects, and effective management, ed. Hosam M. Saleh *Strategies of Sustainable Solid Waste Management* DOI: 10.5772/intechopen.93601

Adenipekun C. O. and Lawal R. (2012). Uses of mushrooms in bioremediation: A review *Biotechnology and Molecular Biology Reviews,* 7(3), 62 – 68.

Akhtar N. and Mannan M. A (2020). Mycoremediation: Expunging environmental pollutants *Biotechnology Reports* 26 (2020) e00452

Akpasi, S. O., Anekwe, I. M. S., Tetteh, E. K., Amune, U. O., Shoyiga, H.O., Mahlangu, T. P. and Kiambi, S. L. (2023). Mycoremediation as a Potentially Promising Technology: Current Status and Prospects— A Review. *Applied Science*, 13, 4978. https://doi.org/10.3390/app13084978

Andersen M. R, Salazar M. P, Schaap P. J, van de Vondervoort P, J, Culley D, Thykaer J, et al. (June 2011). "Comparative genomics of citric-acid-producing Aspergillus niger ATCC 1015 versus enzyme producing CBS513.88". *Genome Research*, 21(6), 885–897.

Ayilara M. S., Akinola, S. A., Omole R. K., Ogundolie F. A., Adeleke B. S., Fayose, C. A., Johnson R. M., Babalola O. O., Adeyemi U. T., Adebajo, M. T., Gbadegesin L. A. and Edhemuino M. (2023). Remediation by enhanced natural attenuation; an environment-friendly remediation approach. *Frontier Environmental Science,* 11.1182586.doi:10.3389/fenvs.2023.1182586

Bennet, J. W., Connick, W. J., Daigle, D. and Wunch, K. (2001). Formulation of fungi for *in situ* bioremediation. In: Fungi in bioremediation, ed. Gadd, G.M., 97 – 108. USA: *Cambridge University Press.*

Boopathy, R. (2005). Factors limiting bioremediation technologies. *Bioresource Technology,* 74 (1), 63-67.

Borokini T. I., Babalola F. D., Amusa T. O., Ivande S. T., Wala Z. J., Jegede O. O., Tanko D., Ihuma, J. O. (2012). Community-based forest resources management in Nigeria: Case study of Ngel Nyaki Forest Reserve, Mambilla Plateau, Taraba State, Nigeria. *Journal of Tropical Forestry and Environment,* 2(1), 69 – 76.

Cotter, T. (2014). Introduction to mycoremediation. *Organic Mushroom Farming and mycoremediation*, Chelsea Green Publishing, Vermont, 291-292.

D"Annibale, A., Rosetto, F., Leonardi, V., Federici, F. and Petruccioli, M. (2006). Role of autochthonous filamentous fungi in bioremediation of a soil historically contaminated with aromatic hydrocarbons. *American Society of Microbiol*ogy, 72(1), 28–36.

Emmanuel E., Usman A. A., Daraobong U. and Opaluwa Q. (2017). Bioremediation potentials of some indigenous microorganisms isolated from auto mechanic workshops on irrigation water using Lokoja Kogi State of Nigeria. *Journal of Bacteriology and Mycology,* 4(4), 121 – 125.

González-González, R. B., Flores-Contreras, E. A., Parra-Saldívar, R., and Iqbal, H. M. N. (2022). Bio-removal of emerging pollutants by advanced bioremediation techniques. *Environmental Research,* 214, 113936. doi: 10.1016/j.envres.2022.113936

Goutam, J., Sharma, J., Singh, R., and Sharma, D. (2021). "Fungal-mediated bioremediation of heavy metal–polluted environment," in *Microbial rejuvenation of polluted environment*: Volume 2. Eds. D. G. Panpatte and Y. K. Jhala (Singapore: Springer Singapore), 51–76.

Hauke, H.**,** Schlosser, D. and Wick, L. Y. (2011). Untapped potential: exploiting fungi in bioremediation of hazardous chemicals. *Nature Review Microbiology,* 9 (3), 177-192.

Isikhuemhen, O. S., Anoliefo, G. O. and Oghale, O. I. (2003). Bioremediation of crude oil polluted soil by white rot fungus, *Pleurotus tuberregium* (Fr.) Sing. *Environmental Science and Pollution Research* 10:108-112.

Itodo S. A. (2011). Environmental sustainability attitude towards environmental pollution in Nigeria proper waste disposal. Treating our environment with respect

Kulshrestha, S., Mathur, N., Bhatnagar, P. (2014). Mushroom as a product and their role in mycoremediation. AMB Express, Springer, 4 (29), 1-7. *lignocellulosic materials* (Ed.). M. P. Coughlan and Collaco, 311 -321. *Elsevier*, London, U.S.A.

Labarère, J and Menini G. U. (2000). Collection, Characterization, Conservation and utilization of mushrooms, germplasm resources in Africa. In: The Proceedings of the First International Congress for the Characterization, Conservation, Evaluation and Utilization of Mushroom Genetic Resources for Food and Agriculture. FAO, Bordeaux, France; 9-13, March, 1998.

Mishra, M. and Srivastava, D. (2020). Mycoremediation: A Step towards Sustainability. *International Journal of Plant and Environment,* 6(4), 298-305.

Mohammed R., Boothman C., Song H., Llyod J. R. and vanDongen B. E. (2024). Asssessing the impacts of oil contamination on microbial communities in a Niger-Delta soil. *Science of the Total Environment* 926(2024), 171813

Ogbeide, O. and Henry, B. (2024). Addressing Heavy Metal Pollution in Nigeria: Evaluating Policies, Assessing Impacts, and Enhancing Remediation Strategies. *Journal of Applied Science Environmental Management,* 28 (4), 1007-1051

Okhuoya, J. A. and Akpaja, E. O. (2005). Mycomedicine and Ethnomycology: The Nigerian Experience. *International Journal of Medicinal Mushrooms.* 7 (3) : 439- 440.

Onwurah I. N. E., Ogugua V. N., Onyike N. B., Ochonogor, A. E and Otitoju, O. (2007). Crude oil spills in the environment: Effect and some innovative clean up biotechnologies through environmental biotechnology. *International Journal of Environmental Research*, 1(4), 307- 320

Osagualekhor, D.O. and Okhuoya, J.A. (2005). Sociocultural and ethnomycological uses of mushrooms among the Esan people of Nigeria. *International Journal of Medicinal Mushrooms,* 7, 442-445.

Osemwegie O. O., Oghenekaro A. O., Ihayere C. A. and Sule E. (2010). Folk uses of mushrooms by the Akoko-Edo people of Nigeria. *Asian Journal of Microbiology, Biotechnology and Environmental Science*, 12(4), 709 – 714.

Ryan M. J., McCluskey K., Verkleij G., Robert V., Smith D. (2019). Fungal biological resources to support international development: challenges and opportunities. *World Journal of Microbiology and Biotechnology*, 35,139.

Sayan-Deb D. and Md.Salman H. (2018). Mycoremediation - a potential tool for sustainable management. A paper presented at state level seminar on population growth and environmental degradation: Present status and future measures at Hiralal Mazumdar Memorial College for Women, Dakshineswar, Kolkata – 700035. https://www.researchgate.net/publication/326273716

Singh, H. (2006). Mycoremediation: Fungal bioremediation. *Wiley*, *New York*, U.S.A.

Thakur, M. (2014). Mycoremediation - a potential tool to control soil pollution, *Asian Journal of Environmental Science Review*, 9 (1), 24-31.

Thomas, S. A**.,** Aston, L. M., Woodruff, D. L. and Cullinan, V. I. (2009). Field demonstration of mycoremediation for removal of fecal coliform bacteria and nutrients in the Dungeness Watershed, Washington. *Pacific Northwest National Laboratory,* Richland, Washington 99352

Vaksmaa, A., Guerrero-Cruz, S., Ghosh, P., Zeghalm E., Hernando-Morales, V. and Niemann, H. (2023) Role of fungi in bioremediation of emerging pollutants. *Frontiers in Marine Science,* 10:1070905. doi: 10.3389/fmars.2023.1070905

Wasser, P. S. (2007). A book review; mycelium running: how mushrooms can help save the world. *Herbalgram,* 76, 50-57.