**Mycoremediation of Heavy Metals from Wupa River Using *Aspergillus niger* and *Aspergillus fumigatus***

**ABSTRACT**

Water pollution by heavy metals poses significant environmental and health risks, particularly in regions with high anthropogenic activities. This study evaluated the bioremediation potential of *Aspergillus niger* and *Aspergillus fumigatus* for heavy metal removal from water samples collected from the Wupa River in Abuja, Nigeria. The physicochemical parameters and heavy metal concentrations (lead, copper, and zinc) of the water samples were analyzed. The fungi were screened for their ability to remediate heavy metals, and their removal efficiency was assessed over an 8-day period. The results showed that *Aspergillus niger* achieved the highest removal efficiency for zinc (90%), while *Aspergillus fumigatus* was most effective for lead (83.77%). The consortium of both fungi demonstrated significant removal efficiency for all three metals, with lead removal reaching 83.77%. This study highlights the potential of fungal bioremediation as a sustainable and eco-friendly method for heavy metal removal from contaminated water bodies.

Keywords: Bioremediation, Heavy metals, *Aspergillus niger*, *Aspergillus fumigatus*, Wupa River,

1. **INTRODUCTION**

Water is a valuable natural resource that covers around 70% of the total earth's surface. Water bodies are crucial because they provide a significant portion of the water needed to sustain life on Earth, and their scarcity may have an impact on both domestic and agricultural activities (Mishra, 2023; Mohammed et al., 2024; Ibrahim et al., 2024a). Freshwater use has grown by 10% between 2000 and 2010 as a result of recent expansion in global population. The majority of freshwater worldwide is utilized for irrigation of farms (40%) and 20–40% is used for human use (Mohammed et al., 2020; Mohammed et al., 2021). Water Pollution has a variety of distinct sources, including the discharge of industrial and field waste into the nearest water bodies, oil tanker leaks, the overuse of fertilizers, and pesticides for crop protection, sewage sludge, and many others (Ibrahim et al., 2023). The major causes of aquatic pollution are prevalent in urban areas, activities like the direct release of polythene bags into rivers and streams (Mohammed et al., 2021), excessive chemical use, dirt, dust, and debris, and irrational use of chemicals. When introduced into aquatic habitats, contaminants including petroleum hydrocarbons, heavy metals, and pesticides can have a direct harmful effect (Adamu et al., 2022). Water pollution with heavy metals is one of the greatest consequences of industrialization in the area of mining, petroleum refining, automobiles, and paints (Montase et al., 2022).

Heavy metals have been defined and described as “naturally occurring metals having atomic number greater than 20 and an elemental density greater than 5 g cm⁻³. Heavy Metals are prominent contaminants because they are toxic and non-biodegradable in the environment, and easily accumulated in living organisms (Montas et al., 2022; Ibrahim et al., 2024b).

Microbial bioremediation is enhanced by the vast diversity of microorganisms, each equipped with unique metabolic pathways that enable them to break down or transform a wide range of contaminants (Ibrahim et al., 2024 a&c). Some microorganisms can exhibit a remarkable ability to adapt to novel compounds, a trait that is further enhanced by their short lifespan and high rates of evolutionary adaptation. Some microbes can even utilize hazardous compounds as energy sources or cellular building blocks. Additionally, genetic manipulation can be employed to enhance or design microbial metabolisms to target specific pollutants. With advancements in synthetic biology, microbial communities can also be engineered to address particular pollution scenarios (Borchert et al., 2021; Xiang et al., 2021). Bioremediation strategies can be categorized as either in situ, where pollution is treated at its original location, or ex situ, where the contaminated material is removed and treated elsewhere. A common example of microbial bioremediation is the cleanup of industrial spills, including oil spills (Patel et al., 2019). In such cases, two approaches are commonly used: bioaugmentation, which involves introducing specific microbes to the pollution site, and biostimulation, which enhances the activity of the existing microbial community to accelerate degradation processes (Sharma et al., 2020).

Mycoremediation, the use of fungi for bioremediation, is an eco-friendly and cost-effective approach for addressing soil and water pollution (Ibrahim et al., 2024d). Fungi possess several advantageous characteristics, including robust growth, an extensive hyphal network, the production of adaptable extracellular ligninolytic enzymes, a high surface area-to-volume ratio, resistance to heavy metals, and the ability to thrive under varying pH and temperature conditions. Additionally, fungi contain metal-binding proteins, making them highly effective in the remediation of diverse pollutants (Khan et al., 2019). Mycoremediation can be applied in situ to treat pollutants such as dyes, herbicides, and pharmaceutical waste, or alternatively, it can be conducted in bioreactors—controlled systems designed to maintain optimal physicochemical conditions for microbial growth (Aragão et al., 2020). Various harmful compounds can be degraded by fungi, and modifying local soil and water conditions can further stimulate biological activity, thereby enhancing the breakdown and removal of toxic substances (Muzhda & Yahya, 2023).

Furthermore, fungi have proven effective in the removal of heavy metals such as lead (Pb) and cadmium (Cd). They accumulate these metals from water and store them in their tissues, such as mycelia or fruiting bodies, as they exist in their simplest form and cannot be further degraded. However, once fungi have been used for mycoremediation, they must be treated as hazardous waste (Muzhda & Yahya, 2023). Since heavy metals are stable, persistent environmental contaminants that cannot be decomposed or destroyed, they pose significant environmental and health risks. This necessitates the development of efficient and cost-effective technologies for detoxifying metal-contaminated sites. The use of fungi and other microorganisms offers a promising solution to this challenge. This study aims to evaluate the efficiency of two types of fungi in mycoremediation.

**2. Materials and Methods**

**2.1 Study Area and Sample Collection**

Water samples were collected from Wupa River, Abuja, at locations influenced by anthropogenic activities. Samples were then transported to the laboratory in sterile plastic bottles for analysis.

**2.2 Physicochemical Analysis** Parameters including temperature, pH, electrical conductivity, turbidity, dissolved oxygen (DO), and biochemical oxygen demand (BOD) were measured using standard APHA (2012) methods as described by Oladeji, (2020).

**2.3 Heavy Metal Analysis** method described by Rashed & Muhammed, (2021) was used to anlyze the Lead (Pb), copper (Cu), and zinc (Zn) concentrations were determined using Atomic Absorption Spectrophotometry (AAS). Standard solutions were prepared for calibration, and results were compared to WHO permissible limits.

**2.4 Fungal Preparation and Bioremediation Experiment** Pure isolates of *A. niger* and *A. fumigatus* were obtained from the Nigerian Institute for Pharmaceutical Research and Development (NIPRD). Fungal inocula were prepared in potato dextrose broth and introduced into contaminated water samples. Bioremediation was monitored over 8 days, with residual metal concentrations analyzed post-treatment (Hassan et al., 2019).

**3. Results**

## 3.0 Physicochemical parameters of water samples collected from Wupa River;

The mean physicochemical parameters of water samples collected from Wupa River are presented in table 1. All the measured physicochemical parameters observed in water sample from Wupa River are within the world health organization maximum permissible limit for freshwater

**Table 1****: Physicochemical parameters of water samples collected from Wupa River**

|  |  |  |
| --- | --- | --- |
| Parameters  | Mean ± S.E | WHO permissible limit |
| Temperature  | 28.6 ± 0.11 | 40 |
| pH | 7.21 ± 0.07 | 7.0 – 8.5 |
| Conductivity  | 0.25 ± 0.00 | 600 |
| BOD | 4.45 ± 0.59 | 5 |
| DO | 5.09 ± 0.05 | 5 |
| Turbidity | 4.71 ± 0.14 | <40 |
| Chloride | 5.26 ± 1.12 |  |
| Sulphate  | 12.00 ± 1.90 | 250-400 |
| Nitrate  | 20.53 ± 0.50 | 50 |
| Total hardness | 10.43 ± 0.26 |  |
|  |  |  |

**3.2 Heavy metal concentration of water samples collected from Wupa River**

The heavy metal concentration of water samples collected from Wupa River are presented in Table 2. Lead record highest (11.09 ± 0.84 mg/L) in terms of mean concentration while zinc record lowest. All the heavy metal observed in water sample from Wupa River are within the world health organization maximum permissible limit for freshwater.

**Table 2** **Heavy metal concentration of water samples collected from Wupa River**

|  |  |  |
| --- | --- | --- |
| Heavy metal  | Mean ± S.E | WHO permissible limit |
| Lead (Pb)  | 11.09 ± 0.84 | 0.02 |
| Copper (Cu) | 5.49 ± 0.05 | 1.3 |
| Zinc (Zn) | 0.10 ± 0.00 | 0.12 |

**Table 3 Heavy metal bioremediation removal of *Aspergillus niger* and *Aspergillus fumigatus* in water samples collected from Wupa River**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameters  | Control | AN | AF | ANF |
| Temperature  | 28.6 ± 0.11 | 26.63 ± 0.37 | 26.9 ±0.52 | 26.73 ± 0.45 |
| pH | 7.21 ± 0.07 | 8.01 ± 0.00 | 8.02 ± 0.04 | 7.95 ± 0.10  |
| Conductivity  | 0.25 ± 0.00 | 0.19 ± 0.03 | 0.21 ± 0.02 | 0.22 ± 0.01 |
| BOD | 4.45 ± 0.59 | 2.88 ± 0.13 | 2.50 ± 0.49 | 2.65 ± 0.40 |
| DO | 5.09 ± 0.05 | 2.53 ± 0.54  | 2.62 ± 0.49 | 3.07 ± 0.09 |
| Turbidity | 4.71 ± 0.14 | 2.88 ± 0.32 | 3.04 ± 0.13 | 3.00 ± 0.91 |
| Chloride | 5.26 ± 1.12 | 2.41 ± 0.63 | 2.33 ± 0.58 | 2.30 ± 0.38  |
| Sulphate  | 12.00 ± 1.90 | 5.44 ± 2.31 | 4.54 ± 0.77 | 3.72 ± 0.44 |
| Nitrate  | 20.53 ± 0.50 | 8.39 ± 0.81 | 6.48 ± 0.85 | 6.13 ± 0.95 |
| Total hardness | 10.43 ± 0.26 | 8.44 ± 0.38 | 7.52 ± 0.52 | 7.02 ± 0.12 |
| Lead | 11.09 ± 0.84 | 3.63 ± 0.41 | 3.62 ± 0.73 | 1.80 ± 0.18  |
| Cupper | 5.49 ± 0.05 | 3.05 ± 0.05 | 1.91 ± 0.12 | 1.25 ± 0.42 |
| Zinc | 0.10 ± 0.00 | 0.009 ± 0.00 | 0.01 ± 0.00 | 0.003 ± 0.00 |

## 3.3 Screening of *Aspergillus niger* and *Aspergillus fumigatus* for heavy metal removal in water samples collected from Wupa River

The potentials of heavy metal removal of *Aspergillus niger*in water samples collected from Wupa River are shown in figure 1. The absorbance of *A niger* increases from day 1 in all the treated heavy metals and the control sample which record increase in absorption as sampling day increases (Figure 1).

Figure 1. The potentials of heavy metal removal of *Aspergillus* *niger* in prepared heavy metal stock solutions.

**3.4 Heavy metal removal efficacy of *Aspergillus niger* and *Aspergillus fumigatus* in water samples collected from Wupa River**

The potentials of heavy metal removal of *Aspergillus niger* and *Aspergillus fumigatus* in water samples collected from Wupa River are shown in figure 2 to 7. Water samples treated with *Aspergillus niger* (AN), *Aspergillus fumigatus* (AF) and combination of *Aspergillus niger* and *Aspergillus fumigatus* shows a good Bioremoval efficacy as there was significant reduction in all the heavy metals of the water samples. Figures 2–4 displayed the bioremoval efficiencies of *Aspergillus niger* and *Aspergillus fumigatus* for Pb, Cu, and Zn in treatment water. The A. niger and A. fumigatus consortia achieved the highest removal efficiency for Pb (83.77) and Cu (77.05), while *A. niger* alone recorded the lowest values for these metals (67.18 for Pb and 44.26 for Cu). For Zn, the highest efficiency (90) was observed in the individual cultures of *A. niger* and *A. fumigatus*, with the consortia showing the lowest efficiency (70). Figures 5–7 present the mean percentage removal of heavy metals from wastewater, where *A. niger* demonstrated its highest removal in Zn (90) and lowest in Cu (44.26), *A. fumigatus* similarly excelled in Zn (90) but was least effective in Cu (65.21), and the consortia achieved the highest removal for Pb (83.77) while recording the lowest for Zn (70).

Figure 2: Bioremoval efficiency of *A.niger* and *A. fumigatus* for lead
Key: *Aspergillus niger*(AN), *Aspergillus fumigatus*(AF), *Aspergillus niger*+ *Aspergillus fumigatus(*ANF*)*

Figure 3: Bioremoval efficiency of *A.niger* and *A.fumigatus* for copper
Key: *Aspergillus niger*(AN), *Aspergillus fumigatus*(AF), *Aspergillus niger*+ *Aspergillus fumigatus(*ANF*)*

**Figure 4**: Bioremoval efficiency of *A. niger* and *A. fumigatus* for zinc
Key: *Aspergillus niger*(AN), *Aspergillus fumigatus*(AF), *Aspergillus niger*+ *Aspergillus fumigatus(*ANF*)*

Figure 5: Bioremoval efficiency of heavy metals for *Aspergillus niger*key:Lead(pb), Copper(Cu), Zinc(Zn)

Figure 6: Bioremoval efficiency of heavy metals for *Aspergillus fumigatus*key:Lead(pb), Copper(Cu), Zinc(Zn)

Figure 7: Bioremoval efficiency of heavy metals for *A. niger* and *A. fumigatus* consortia
key:Lead (pb), Copper(Cu), Zinc(Zn)

##

**4. Discussion**

The presence of heavy metals in water bodies poses serious risks to both human health and aquatic ecosystems. Persistent pollutants such as lead (Pb), copper (Cu), and zinc (Zn) do not degrade naturally and tend to accumulate in biological systems over time (Ibrahim et al., 2023; Ibrahim et al., 2024a, b & c). In this study, water samples collected from Wupa River exhibited heavy metal concentrations exceeding WHO permissible limits, underscoring the severity of contamination in the region. The elevated levels of Pb and Cu are likely due to industrial effluent discharge and wastewater treatment plant runoff.

Bioremediation using fungi, particularly Aspergillus niger and Aspergillus fumigatus, has shown great potential in mitigating heavy metal contamination. These fungi produce organic acids, such as citric and oxalic acids, which enhance the solubilization and bioavailability of heavy metals, facilitating their removal from contaminated environments (Ibrahim et al., 2024a). Additionally, their metal-binding proteins and enzymatic systems enable them to bioaccumulate, transform, or degrade toxic pollutants, making them effective agents for soil and water remediation (Dwivedi, 2023).

The findings of this study reveal that both fungal species significantly reduced Pb, Cu, and Zn concentrations in water samples, with the highest removal efficiency recorded for Zn (90%). These results align with previous studies in Wupa wastewater, where Aspergillus niger achieved a 98% reduction in zinc levels (Ibrahim et al., 2024b), while Bacillus subtilis demonstrated an even higher removal efficiency of 99% (Ibrahim et al., 2024b & c). The ability of these fungi to sequester heavy metals can be attributed to their cell wall composition, which contains functional groups such as carboxyl, amino, and hydroxyl groups that facilitate metal binding (Priyadarshini et al., 2021). Furthermore, extracellular enzymes produced by these fungi enhance metal chelation, further increasing their bioremediation potential (Dinakarkumar et al., 2024).

The efficiency of A. niger and A. fumigatus in heavy metal removal is also influenced by environmental factors such as pH, temperature, and dissolved oxygen levels. The observed increase in pH following fungal treatment suggests that their metabolic activities contribute to the neutralization of acidic contaminants, creating a more favorable environment for metal precipitation and removal (Ibrahim et al., 2024).

A major advantage of fungal bioremediation is its cost-effectiveness and environmental sustainability compared to conventional methods such as chemical precipitation and ion exchange (Ibrahim et al., 2024b). Unlike traditional approaches, fungal bioremediation does not generate secondary waste and can treat large volumes of contaminated water with minimal energy input (Kapahi & Sachdeva, 2019). Additionally, the ability of A. niger and A. fumigatus to thrive in diverse environmental conditions makes them ideal candidates for large-scale bioremediation applications (Borchert et al., 2021).

Despite the promising results observed in this study, several challenges must be addressed to optimize fungal bioremediation processes. The presence of competing ions and organic matter in contaminated water can interfere with metal-binding sites on fungal cell walls, potentially reducing their efficiency (Dhanushree & Hina Kousar, 2017; Dell’Anno et al., 2022). Further research is needed to refine bioremediation strategies and improve heavy metal removal efficiency in complex environmental conditions.

**5. Conclusion and Recommendations**: The findings of this study underscore the potential of *A. niger* and *A. fumigatus* as effective agents for heavy metal bioremediation. Their ability to reduce Pb, Cu, and Zn concentrations, coupled with their production of bioactive secondary metabolites, highlights their significance in sustainable water treatment strategies. Future research should focus on optimizing fungal growth conditions and exploring the potential of fungal consortia to enhance bioremediation efficiency. Additionally, genetic modifications and metabolic engineering approaches could be explored to improve fungal resistance to high metal concentrations and increase biosorption capacity

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