MYCOFILTRATION EFFECTIVENESS IN BIOREMEDIATION OF CONTAMINATED DRINKING WATER SOURCES

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ABSTRACT

Most rural areas in developing countries, Nigeria inclusive, lack access to clean, potable water. It is getting increasingly difficult by the Federal, State and Local Governments, whose primary responsibility it is, to provide pipe-borne potable water for the citizenry. As a result, most rural dwellers rely on untreated water from wells, streams, ponds, boreholes and rivers for consumption. This study was therefore undertaken to investigate the efficacy of mycoremediation capacity of a mycelium-permeated substrate as a useful tool for the reduction of toxicity in drinking water sources in rural communities. Contaminated domestic water samples obtained from eighteen rural communities in Warri North, Ughelli North and Ughelli South Local Government Areas in Delta State of Nigeria were bioremediated using mycofiltration technique. Statistical analysis of data obtained after a 24 h mycofiltration treatment on drinking water samples revealed a significant ($p<0.05$) reduction or total elimination of heavy metals and microbial load in the water samples. The findings from the study show that mycofiltration technique is a useful, efficient and affordable technology for toxicity reduction in drinking water sources available for rural dwellers in developing countries.

Keywords: Mycofiltration, Drinking Water, Rural Dwellers, Toxicity

INTRODUCTION

Lack of adequate supply of potable water is a critical challenge in developing countries such as Nigeria. The usual sources of drinking water which are mostly untreated and associated with various health risks are streams, rivers, wells and boreholes (Agbarie and Obi, 2009). One of the primary goals of the World Health Organization (WHO) and its Member States is that "all people, whatever their stage of development and their social and economic conditions, have the right to have access to an adequate supply of safe drinking water" (WHO, 2011). Although Nigeria is known to be endowed with abundant water resources, the availability of potable water is a problem in many parts of the country. The provision of pipe-borne potable water is the primary responsibility of the Federal, State and Local Governments but unfortunately, access to drinking water is grossly inadequate both in quantity and quality (Onokerhoraye, 1995).

The quality of water influences the health status of any populace hence any analysis of water for physical, biological and chemical properties including trace element content are very important for public health studies. Ground water is an important resource in both the urban and rural areas in Nigeria (Adekunle *et al.*, 2007).

Wastes generated from industrial activities and natural disasters have continued to pose serious challenge to mankind. Millions of tonnes of organic xenobiotics considered to be emerging contaminants enter the environment via effluents from wastewater treatment plants and accidental spillage during various industrial applications. As a result of these extensive environmental inputs, water bodies such as rivers, lakes and groundwater used as drinking water resources have become contaminated with a wide range of organic pollutants needing urgent attention to remediate the fast degrading environment (Leung, 2004).

The Niger Delta region of Nigeria is regarded as the treasure bed of the country as more than 95% of Nigeria's foreign earnings come from there, and it is characterized by an interwoven network of ditches, ponds, rivulets, streams, lakes, rivers, estuaries, and a characteristic shallow water table that, incidentally, is the only source of domestic water supply. Oil exploration and exploitation have been dominant activities in the area for more than 40 years. Crude and refined oil spillages, gas flares, and industrial effluents have impacted negatively on the arable land and the aquatic ecosystem, and there is serious pollutant-atmospheric interaction. Streams, shallow wells, and boreholes form the major sources of potable water supply for the different communities in the Niger Delta. Water treatment is rarely carried out at the household level (Nduka and Orisakwe, 2010). Rural dwellers in this region are faced with the challenge of providing low-cost, low impact, non-toxic and easy-to-deploy methods for removing pathogens, organic and inorganic contaminants from their drinking water sources.

The treatment of environmental problems through biological means known as bioremediation, involves the elimination, attenuation or transformation of polluting or contaminating substances. Biological agents, mainly microorganisms (yeast, fungi or bacteria) and plants are used to degrade or detoxify substances hazardous to human health and/or the environment (Fulekar and Pandey, 2012). Bioremediation is environment-friendly and a cost-effective approach when compared with chemical and physical methods of managing wastes (Sharma *et al.*, 2010).

Mycoremediation, a form of bioremediation, is the application of fungi such as *Phanerochaete* sp., *Pleurotus* sp., *Trametes versicolor*, *Nematoloma frowardii*, and *Irpex lacteus* in the remediation of polluted soils and aqueous effluents (Šašek and Cajthaml, 2005). It involves mixing mycelium into contaminated soil, placing mycelium mats over toxic sites, or a combination of these techniques, in one time or successive treatments (Stamets, 2005). Fungi are well suited for uptake and removal of metals and other pollutants from wastewater and soil because they often exhibit marked tolerance toward metals and adverse conditions like low pH, and accomplish remediation by processes such as insoluble metal oxalate formation, biosorption or chelation onto melanin-like polymers (Singh *et al.*, 2011). The fungi mostly used, the white-rot fungi, or their enzymes are able to transform and mineralize *in vitro* or *in vivo*, many environmental organo-pollutants, including pesticides, munitions waste, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, wood preservatives, synthetic dyes and waste materials from paper producing plants (Robles-Hernandez *et al.*, 2008). The use of the fungus, *Pleurotus tuberregium* for the scavenging of heavy metals from aqueous effluents at low pH and economic treatment of Cd^{2+} and Se^{4+} ions has been suggested (Okuo *et al.*, 2008, 2009).

Mycofiltration, a very similar process to mycoremediation, is the use of mycelial mats to filter toxic waste and microorganisms from polluted water. Mycofiltration membranes have been applied to filter pathogens including protozoa, silt, chemical toxins, bacteria and viruses (Stamets, 2005). The objective of this study was to determine the effectiveness of a mycelium-permeated substrate in removing pollutants from contaminated drinking water sources in some rural communities in Delta State, Nigeria.

MATERIALS AND METHODS

Study Site

Drinking water samples from boreholes, streams, rivers, hand-dug wells, and a pond were collected from eighteen communities in three Local Government Areas (Warri-North, Ughelli-South and Ughelli-North) of Delta State of Nigeria for the study (Fig. 1-3). The communities in Warri-North were Koko Town (A1), Koko Beach (A2), Aja-Olugbeti (A3), Ajayite (A4), Ugbegbelemeji (A5) and Ubielegbe (A6). Those in Ughelli-South were Esaba (B1), Ophorigbala (B2), Owahwa (B3), Iwhreogun (B4), Otuwoama (B5) and Okwagbe (C6). The communities located in Ughelli North Local Government Area were Inene (C1), Ujode (C2), Ogbovwa (C3), Emeragha (C4), Owharo (C5) and Omavovwe-Agbarha-Otor (C6).

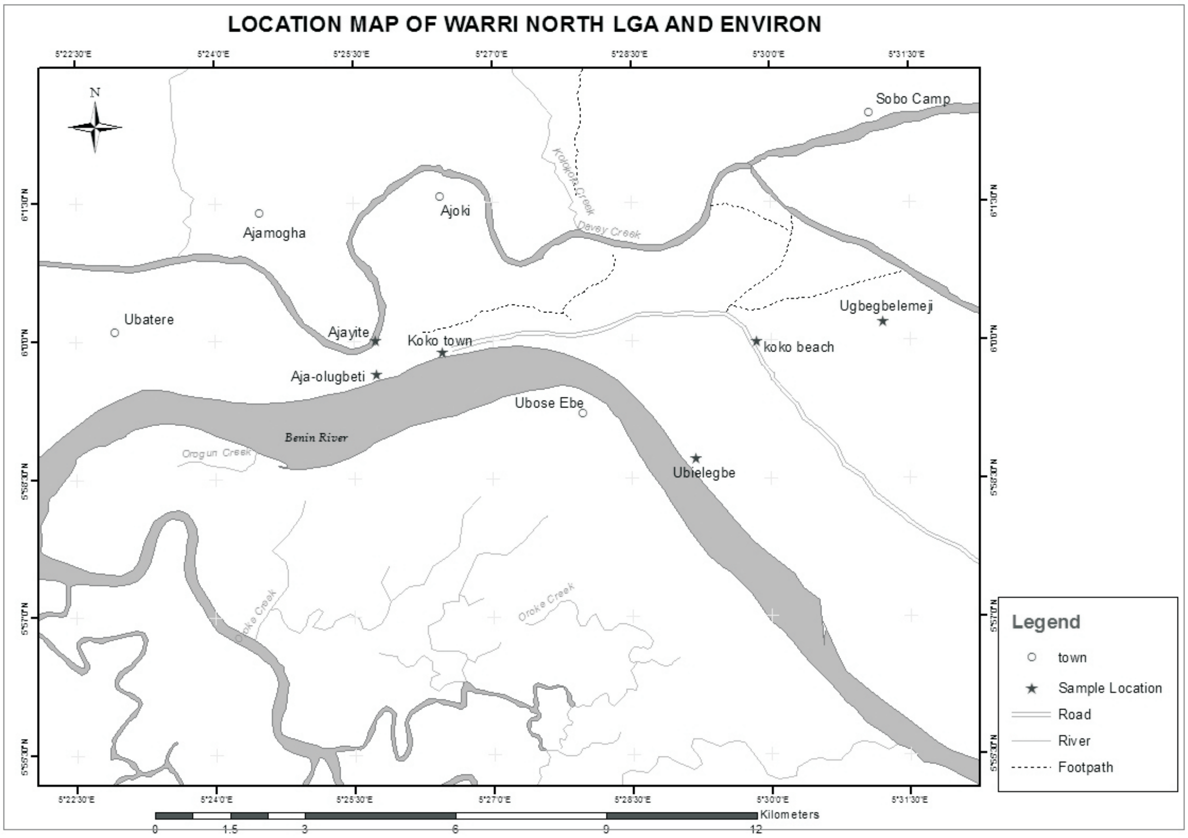

Fig. 1: Map of Warri North Local Government Area and environs showing location of sample collection

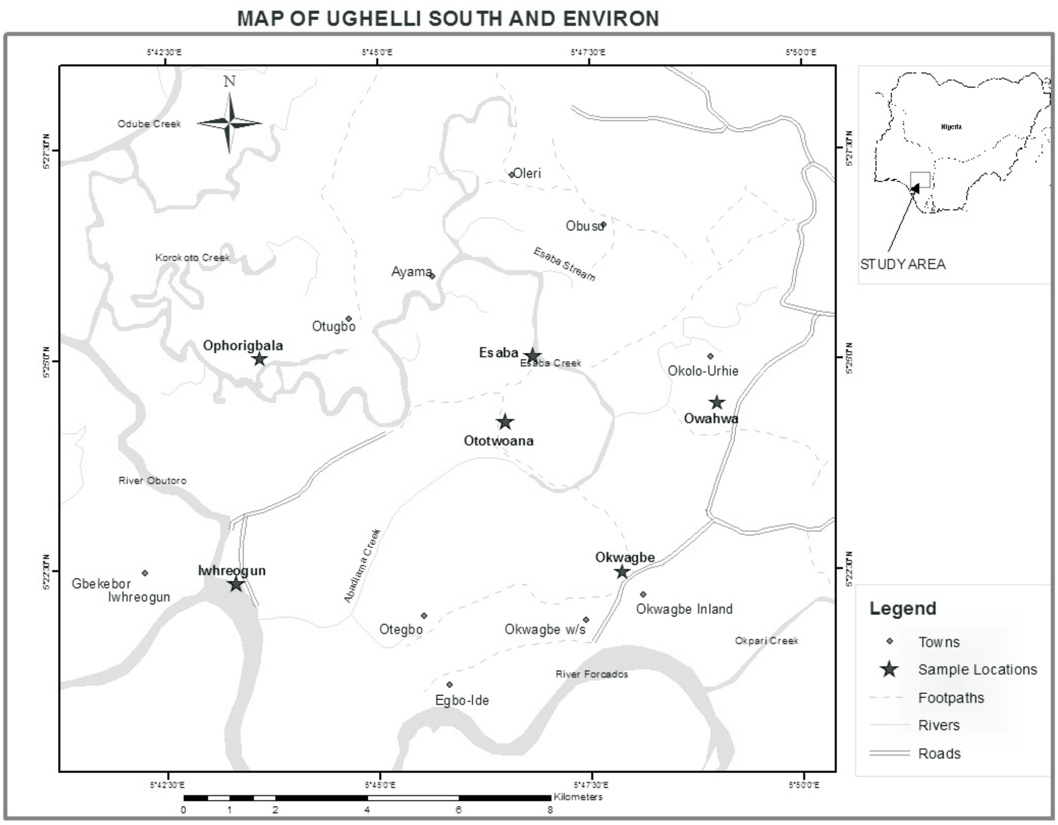

Fig. 2: Map of Ughelli South Local Government Area and environs showing location of sample collection

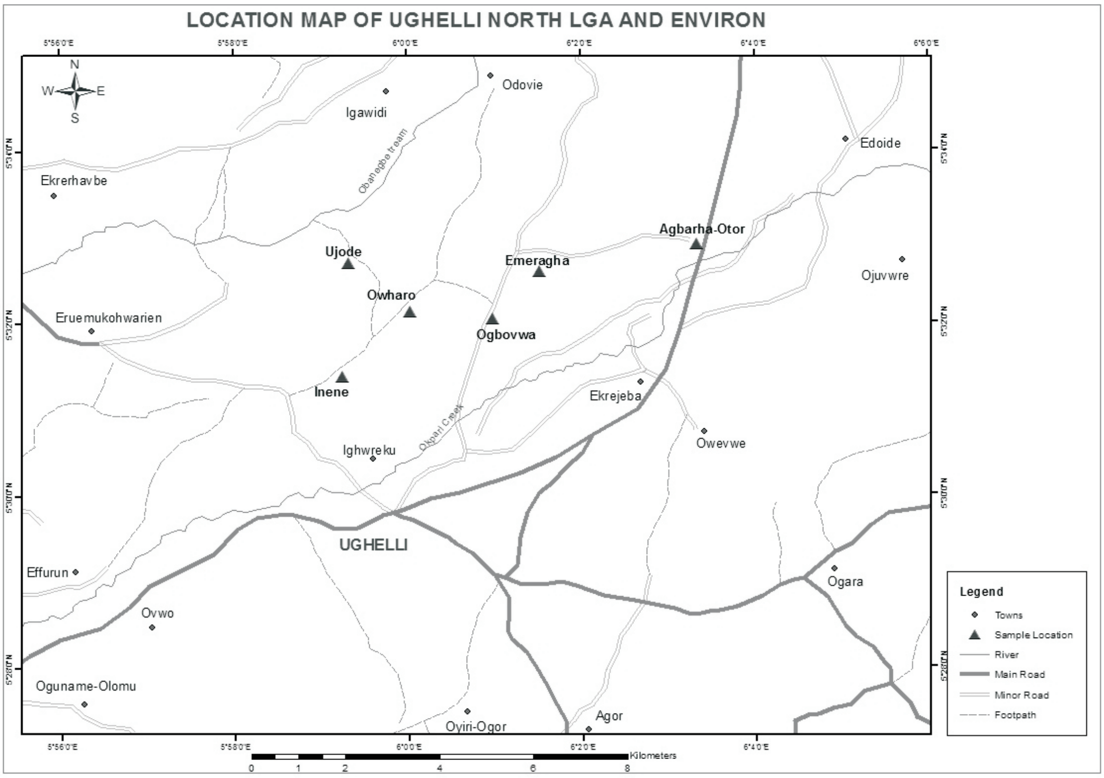

Fig. 3: Map of Ughelli North Local Government Area and environs showing location of sample collection

Collection, Physicochemical and Microbiological Analysis of Water Samples

The water samples for the study were collected in March, 2013 from rivers, streams, wells, boreholes and a pond. Water samples from rivers, streams, wells and the pond were collected at different depths from three random points within the water body in a triangular equilibrium using sterile plastic bottles. The samples were filtered using filter paper with a pore size of 5 µm before analysis. For the borehole, sampling protocols described by Claasen (1982), Barcelona *et al*., (1985), and APHA (2005) were slightly modified during sampling collection. The nozzle of the boreholes were swabbed with cotton wool soaked in 70% (v/v) ethanol and flamed for 2 min. Samples were collected using washed and sterilized plastic containers after running water to waste for 1 min. In both cases, samples were taken aseptically into plastic containers, kept in an ice chest and stored in the refrigerator at 4 °C. Analysis was done within 24 h of collection. The pH of the samples were taken *in situ* using a Suntex® SP-707 (Taipei, Taiwan) portable pH meter.

The water samples were analysed for twelve metals namely: lead, copper, cadmium, chromium, iron, zinc, manganese, aluminium, cobalt, silver, arsenic and nickel according to standard analytical methods (USEPA, 1996; APHA, 2005) using an Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer A Analyst 100). The metal standards were prepared to known concentrations, labeled, and kept inside plastic bottles that were pre-cleansed with concentrated nitric acid and distilled water. For microbial analysis, the techniques employed were estimation of total heterotrophic bacteria (THB) by plate count technique and estimation of coliform bacilli by MPN presumptive test (APHA, 1998).

Mycofiltration Procedure

Maize cobs were collected from local corn sellers in Iyowa village near Benin City and milled to dust particles and then sundried to constant weight to reduce moisture content. For the preparation of the substrate, 77% of the unfermented maize cob dust was supplemented with 20% (w/v) wheat bran, 1% (w/v) granulated sugar, 1% (w/v) calcium sulphate and 1% (w/v) calcium carbonate. This was mixed properly with water, covered with tarpaulin and allowed to compost for 7 days. To ensure homogenous fermentation, the substrate was mixed by turning every 48 h. The substrate was thereafter loaded into bags (15 x 30 cm) and pasteurized by steaming it for 3 h to reduce contaminants after which it was allowed to cool in a sterile room. After cooling, the substrate was inoculated at the centre with a spawn of *Pleurotus tuberregium* and allowed to incubate at ambient temperature (26±2 °C) until it was fully colonised by the mycelium of the mushroom.

The colonized substrate which has a hollow made in the middle of it was put in a perforated bowl and the collected drinking water samples separately filtered through the mycelium-permeated maize cob dust substrate.

Data Analysis

Quantitative data for pH and other physicochemical parameters were summarised as means ± standard errors, which were then subjected to Duncan multiple comparison and Dunetts tests in a one-way ANOVA, using SPSS version 15.0 for Windows 2007. Significant differences were set at $p \leq 0.05$.

RESULTS

The average values of physico-chemical characteristics of the drinking water samples from the 18 rural communities in three Local Government Areas in Delta State (Tables 1-3) revealed that the drinking water sources were contaminated to varying degrees. Some of the heavy metals in most of the water samples were found at concentrations above national (SON) and international (WHO) regulatory limits and the most polluted of the water samples were found in those obtained in Warri-North Local Government Area.

The tables also showed the effect of mycofiltration treatment of drinking water sources on pH and heavy metal content in some rural communities in Warri-North, Ughelli South and Ughelli North Local Government Area of Delta State. Most of the water samples were acidic, Okwagbe well water being the most acidic with a pH of 4.1; while Owharo borehole water was basic with a pH of 9.7. Treatment with the mycelium-permeated filter ameliorated all the acidic samples to manageable levels between pH 6.0 - 7.1 while the alkaline water was ameliorated to pH 8.6.

Likewise, the high amounts of heavy metals found in the water samples were either drastically reduced or totally removed. For instance, Fe which was initially 11.60±0.01 mg/l in Koko Town borehole water (Table 1) was reduced to 0.61±0.00 mg/l after filtration. Zinc and lead, with initial concentrations of 23.0±0.04 mg/l and 0.23±01 mg/l respectively in Ubielegbe pond water were totally eliminated after filtration. Similar results were obtained for drinking water samples in other Local Government Areas.

Table 1: Effect of mycofiltration treatment of drinking water sources on pH and heavy metal content in some rural communities in Warri-North Local Government Area of Delta State

Water sample	Water source	Treatment	pH	Concentration of metal (mg/l)											
				Fe	Zn	Cr	Pb	Mn	Cd	Al	Co	Ag	Cu	As	Ni
A1	BH	NF	5.2	11.60±0.01	14.90±0.01	0.14±0.00	0.02±0.00	0.02±0.00	0.12±0.00	0.10±0.00	0.00±0.00	0.05±0.00	0.05±0.00	0.00±0.00	0.00±0.00
		MF	6.1	0.61±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
A2	BH	NF	5.3	9.70±0.01	8.50±0.01	0.12±0.00	0.01±0.00	0.01±0.00	0.11±0.00	0.05±0.00	0.00±0.00	0.10±0.00	0.03±0.00	0.00±0.00	0.00±0.00
		MF	6.1	0.92±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00
A3	BH	NF	5.3	3.80±0.01	5.50±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	6.4	0.40±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
A4	ST	NF	5.3	6.80±0.02	7.80±0.01	0.00±0.00	0.00±0.00	0.01±0.00	0.05±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00
		MF	6.1	0.40±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
A5	ST	NF	5.5	5.70±0.01	0.00±0.00	0.04±0.00	0.04±0.00	0.00±0.00	0.10±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	6.2	1.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
A6	PD	NF	4.8	16.50±0.03	23.00±0.90	0.23±0.00	0.23±0.00	0.10±0.00	0.19±0.00	0.11±0.00	0.00±0.00	0.09±0.00	0.11±0.00	0.00±0.00	0.10±0.00
		MF	6.1	1.62±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.10±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00
SON (2007) Limit			**6.5-8.5**	**0.30**	**3.0**	**0.05**	**0.01**	**0.20**	**0.003**	**0.20**	-	-	**1.0**	-	**0.02**
WHO (2011) Limit			**6.5-9.2**	**1.0**	**3.0**	**0.05**	**0.01**	**0.40**	**0.003**	-	-	-	**2**	**0.01**	**0.07**

Values are means (± S.E.) of 3 replicates. BH = Borehole water, ST = Stream, RR = River water, PD = Pond water, WL = Well water, NF = Nonfiltrated water, MF = Mycofiltrated water. SON: Standards Organization of Nigeria (2007) permissible limits for drinking water quality

Table 2: Effect of mycofiltration treatment on drinking water sources on pH and heavy metal content in some rural communities in Ughelli-South Local Government Area of Delta State

Water sample	Water source	Treatment	pH	Concentration of metal (mg/l)											
				Fe	Zn	Cr	Pb	Mn	Cd	Al	Co	Ag	Cu	As	Ni
B1	BH	NF	4.8	2.50±0.00	6.10±0/01	0.00±0.00	0.00±0.00	0.04±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	6.0	0.51±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
B2	BH	NF	6.8	2.00±0.00	5.90±0.02	0.00±0.00	0.01±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	7.1	0.63±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
B3	BH	NF	4.2	2.90±0.01	5.10±0.00	0.00±0.00	0.01±0.00	0.03±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.10±0.00	0.00±0.00	0.00±0.00
		MF	6.0	0.72±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00
B4	RR	NF	6.8	6.40±003	13.00±0.40	0.10±0.00	0.11±0.00	0.23±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.02±0.00	0.03±0.00	0.00±0.00	0.00±0.00
		MF	7.1	0.41±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
B5	WL	NF	4.8	3.70±0.00	6.20±0.05	0.01±0.00	0.01±0.00	0.09±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.12±0.00	0.00±0.00	0.00±0.00
		MF	6.1	0.02±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00
B6	WL	NF	4.1	4.10±0.01	6.50±0.02	0.00±0.00	0.03±0.00	0.10±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	6.0	1.21±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
SON (2007) Limit			**6.5-8.5**	**0.30**	**3.0**	**0.05**	**0.01**	**0.20**	**0.003**	**0.20**	-	-	**1.0**	-	**0.02**
WHO (2011) Limit			**6.5-9.2**	**1.0**	**3.0**	**0.05**	**0.01**	**0.40**	**0.003**	-	-	-	**2**	**0.01**	**0.07**

Values are means (± S.E.) of 3 replicates. BH = Borehole water, ST = Stream, RR = River water, PD = Pond water, WL = Well water, NF = Nonfiltrated water, MF = Mycofiltrated water. SON: Standards Organization of Nigeria (2007) permissible limits for drinking water quality

Table 3: Effect of mycofiltration treatment on drinking water sources on pH and heavy metal content in some rural communities in Ughelli-North Local Government Area of Delta State

Water sample	Water source	Treatment	pH	Concentration of metal (mg/l)											
				Fe	Zn	Cr	Pb	Mn	Cd	Al	Co	Ag	Cu	As	Ni
C1	BH	NF	5.8	2.60±0.03	6.90±0.30	0.01±0.00	0.00±0.00	0.02±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	6.1	1.43±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.10±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
C2	BH	NF	6.4	4.30±0.00	7.10±0.21	0.00±0.00	0.03±0.00	0.03±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	7.2	0.30±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
C3	BH	NF	5.1	2.00±0.01	6.40±0.30	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	6.8	0.52±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00
C4	BH	NF	9.7	3.00±0.00	8.00±0.03	0.02±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.10±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	8.6	0.31±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
C5	BH	NF	5.0	2.10±0.01	6.60±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	6.8	0.94±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
C6	BH	NF	5.0	1.90±0.00	5.10±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
		MF	6.7	0.61±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
SON (2007) Limit			**6.5-8.5**	**0.30**	**3.0**	**0.05**	**0.01**	**0.20**	**0.003**	**0.20**	-	-	**1.0**	-	**0.02**
WHO (2011) Limit			**6.5-9.2**	**1.0**	**3.0**	**0.05**	**0.01**	**0.40**	**0.003**	-	-	-	**2**	**0.01**	**0.07**

Values are means (± S.E.) of 3 replicates. BH = Borehole water, ST = Stream, RR = River water, PD = Pond water, WL = Well water, NF = Nonfiltrated water, MF = Mycofiltrated water. SON: Standards Organization of Nigeria (2007) permissible limits for drinking water quality

Results of the microbial examination of the drinking water samples are presented in Table 4. Data obtained revealed a significant ($p<0.05$) reduction or total elimination of total heterotrophic bacteria after filtration.

Table 4: Effect of mycofiltration on the microbiological characteristics of drinking water samples in 18 rural communities in three Local Government Areas in Delta State

Water sample	Water source	Treatment	Total bacterial count† (cfu/ml)	Coliform count‡ (MPN/100 ml)
A1	Borehole	Non-filtrated	11.2×10^3	1.4×10^3
		Mycofiltrated	-	-
A2	Borehole	Non-filtrated	16.3×10^3	2.4×10^3
		Mycofiltrated	3.7×10^3	-
A3	Borehole	Non-filtrated	8.2×10^3	0.6×10^3
		Mycofiltrated	-	-
A4	Stream	Non-filtrated	1.4×10^3	0.4×10^3
		Mycofiltrated	-	-
A5	Stream	Non-filtrated	1.0×10^3	-
		Mycofiltrated	-	-
A6	Pond	Non-filtrated	33.2×10^3	2.8×10^3
		Mycofiltrated	0.4×10^3	-
B1	Borehole	Non-filtrated	18.3×10^3	3.2×10^3
		Mycofiltrated	0.41×10^3	-
B2	Borehole	Non-filtrated	23.6×10^3	4.36×10^3
		Mycofiltrated	4.0×10^3	-
B3	Borehole	Non-filtrated	23.6×10^3	1.4×10^3
		Mycofiltrated	0.6×10^3	-
B4	River	Non-filtrated	1.6×10^3	-
		Mycofiltrated	-	-
B5	Well	Non-filtrated	38.2×10^3	13.4×10^3
		Mycofiltrated	5.6×10^3	3.2×10^3
B6	Well	Non-filtrated	26.30×10^3	11.6×10^3
		Mycofiltrated	5.80×10^3	2.0×10^3
C1	Borehole	Non-filtrated	24.3×10^3	9.4×10^3
		Mycofiltrated	0.5×10^3	-
C2	Borehole	Non-filtrated	12.2×10^3	1.4×10^3
		Mycofiltrated	-	-
C3	Borehole	Non-filtrated	16.3×10^3	2.4×10^3
		Mycofiltrated	3.7×10^3	-
C4	Borehole	Non-filtrated	14.5×10^3	1.2×10^3
		Mycofiltrated	0.2×10^3	-
C5	Borehole	Non-filtrated	27.5×10^3	5.5×10^3
		Mycofiltrated	4.1×10^3	-
C6	Borehole	Non-filtrated	21.6×10^3	0.5×10^3
		Mycofiltrated	2.9×10^3	-

DISCUSSION

The ability of fungi to degrade a wide variety of compounds and materials has been utilised in the cleanup of toxic compounds in wastewaters and for the remediation of polluted soils (Šašek and Cajthaml, 2005). Apart from the hyperaccumulative ability of fungi for metals, they also have the capacity to trap and digest many organisms (Stamets, 2005).The white-rot fungi have been mostly used to transform many environmental organo-pollutants, including pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, wood preservatives, synthetic dyes and waste materials from paper producing plants (Robles-Hernandez *et al*., 2008).

In this study, the mycofilters produced by the fungus *Pleurotus tuberregium* was effectively used to remove heavy metals from contaminated drinking water sources in rural communities in Niger Delta region of Nigeria. The effectiveness of the fungus, *P. tuberregium* to scavenge heavy metals from aqueous effluents at low pH and economic treatment of Cd^{2+} and Se^{4+} ions has been reported (Okuo *et al*., 2008, 2009). In a recent report, the fungus *Pleurotus florida* was used to successfully remove Pb^{2+} ions from effluents (Prasad *et al*., 2013). In a more recent report, Akpaja *et al*. (2014) used the white-rot fungus mycelium-permeated filter to reduce the metallic and cyanide and bacterial load of cassava effluents.

The biological removal of metals from solutions can be divided into three categories; these are: biosorption of metal ions on the surface of fungi, intracellular uptake of metal ions and chemical transformation of metal ions by fungi (Singh, 2006). The particular mechanism(s) of heavy metal removal employed by the fungus, *Pleurotus tuberregium*, in this study is yet to be elucidated. The need to conduct further studies in this regard and investigate the capabilities of other indigenous mushrooms to remove heavy metals from contaminated water has become imperative. This is understandably so as more wastewaters are constantly being generated due to anthropogenic activities in the environment.

CONCLUSION AND RECOMMENDATION

The choice of the Niger Delta geographical region in Nigeria for this study was as a result of the frequent cases of aquatic pollution from anthropogenic activities especially from oil drilling and exploration processes. Results obtained from the study have shown that the use of mycofiltration would serve as a self help and low cost technology using maize cobs as a first tier bioremediation of contaminated drinking water. Large amounts of agricultural wastes including maize cobs are generated from farms in these rural communities. These wastes can be used as substrates in a low cost and efficient cultivation method for the production of fungal filtration membranes to ameliorate their contaminated drinking water.

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