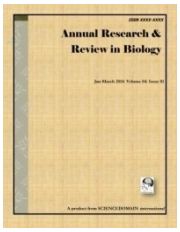

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The Biofiltration Potentials of a Brewery Effluent Using Two Saprophytic Fungi Species

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Authors' contributions

This work was carried out in collaboration between both authors. Author AAAS conceived and designed the study. Authors AAAS and OSA jointly managed the execution, acquisition of the data, statistical analyses of the data as well as the literature search that were reported in this work. Author AAAS interpreted the results of this study while author OSA wrote the initial draft of the manuscript. Both authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: This research attempts to investigate the effect of a biologically mediated filtration technique {using the mycelia from two saprophytic filamentous fungi – *Aspergillus flavus* (*A. flavus*) and *Aspergillus niger* (*A. niger*), isolated from the soil} on the physicochemical indices of an Industrial (Brewery) effluent.
Study Design: The experiment was conducted in a Completely Randomized Design (CRD). In all cases, the value for each data was the mean from 3 replicates. Data were subjected to a one way analysis of variance – ANOVA, while the separation of the means (post Hoc Test) was done using the independent sample T-Test at 1% level of significance.
Place of Study: The Study was conducted at different Institutional Laboratories (such as the Federal Institute of Industrial Research, Oshodi; Environmental Biology Lab., Yaba College of Technology and Chemistry Lab., University of Lagos) in Lagos, Nigeria.
Methodology: The effluent samples were analyzed for various physical parameters such as pH, temperature, turbidity, conductivity and Total Dissolved Solids and chemical parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Phosphates, Sulphates, Chlorides, Hardness, Alkalinity and Nitrates using standard

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laboratory techniques and equipment.
Results: The results obtained from this work showed that both fungal species were able to bring about a significant ($p \leq 0.01$) improvement in most of the physicochemical parameters considered in this Brewery effluent when compared to the unfiltered (Control) effluent samples, as well as against approved benchmarks as provided by some statutory regulatory bodies in Nigeria such as the Lagos State Environmental Protection Agency (LASEPA) and now defunct Federal Environmental Protection Agency (FEPA).
Conclusion: The results from this study shows that *A. niger* and *A. flavus* (that were used in this experiment) has some promise at improving some important physicochemical indicators of a poorly treated brewery effluent.

Keywords: Fungi, Biological treatment of water; water pollution; Brewery effluent; mycofiltration; physicochemical parameters; Aspergillus niger; Aspergillus flavus.

1. INTRODUCTION

Aggressive push towards industrialization is often accompanied by the problem of pollution in a number of the developing nations of the world. In Nigeria for example, the efforts towards the improvement in the various segments of the society is tremendous. This in turn places the concern for the development of the economy as a front burner issue for all the tiers of governments in successive administrations. To this end, the demarcation of certain areas as Industrial Areas and or Free Trade Zones is a common place throughout the Nigerian landscape. Different forms of concessions such as tax relief and or import/export duty waivers are often given by the governments (at all levels) as an inducement to the Industrialists into sitting their Industries in their respective domains. The peculiar characteristic of these Industrial Estates is that most of them lack Central Waste Treatment Plants and therefore, discharge their effluent and emissions and indeed sundry other Environmental Aspects directly or indirectly into the environment.

Industrial effluents are an important source of pollutants/toxicants into the various ecosystems in Nigeria [1,2,3,4]. It is well established that pollution lowers the quality of life in various aspects and affects the health and the life expectancy of organisms. Besides the direct health effects, the subtle danger of pollutants lies in the fact that they may be mutagenic or toxic and could lead to several human afflictions like cancer, atherosclerosis, cardiovascular diseases and premature ageing [5].

In the Industrial nerve centres of Nigeria found mostly in Lagos State and parts of Ogun, Kano, and Rivers States, there are many industries that discharge their effluents untreated into the water bodies around the metropolis [6,7,8].

Untreated effluent poses a major risk to human health since it contains some water borne pathogens that can cause serious illnesses in humans [9]. The symptoms that follow these diseases are fever, headache, kidney damage, sickness, vomiting, diarrhea, abdominal pains, chills, bowel perforation, lack of appetite, fatigue and even death [10]. Untreated effluent and sewage also destroy aquatic ecosystems and threatens human livelihood, especially when the associated biological oxygen demands in the water is depleted too low to sustain life [9].

Waste water treatment process involves a number of steps that are spatially segregated. The first three steps are called primary, secondary, and tertiary treatment. At the end of the process, the water is usually chlorinated before it is released into the water body [11]. Primary treatment step involves the removal of insoluble particulate materials by settling, screening, addition of alum and other coagulation agents, and other physical procedures. Secondary treatment includes the biological removal of dissolved organic matter; freckling filter, activated sludge, lagoons, extended aeration systems, anaerobic digesters, while the tertiary treatment involves the biological removal of inorganic nutrients, chemical removal of inorganic nutrient, virus removal/inactivation, trace chemical (heavy metal) removal [11].

Mycofiltration as a form of biological treatment of waste water involves the use of fungal mycelia as a membrane for filtering out microorganisms, pollutants, and silt [12]. It has been reported that habitats infused with fungal mycelia recorded a reduction in the downstream particulate flow, mitigated erosion, filtered out bacteria and protozoa, and modulated water through the soil [12].

1.1 Aims and Objectives

The general aim of this research was to investigate the ability of some filamentous fungi at remediating industrial effluent in a timely and cost effective manner.

The following are the specific objectives of this work;

(1) To isolate saprophytic filamentous fungi from the soil from a dump site.
(2) To determine the effectiveness of some of these fungal species (in 1 above) at improving some physico-chemical indicators and heavy metal burden in an industrial effluent.

2. MATERIALS AND METHODS

2.1 Materials/Equipment

2.1.1 Collection of samples

The soil from which fungi were isolated (for further use) in this research was collected from Shomolu market, Lagos State, Nigeria located on 6° 31' 38" North, 3° 22' 22" East (Fig. 1). Effluent was collected from Nigerian Brewery (Sona Brewery), Ijako-Ifo, Ogun State, Nigeria located N 06^0 44' 71", E 3^0 12' 98" (Fig. 2).

3.1.2 Isolation of fungi from the soil

Serial dilution 0f up to 10^5 was done using 1g of soil in 10ml of sterile distilled water. Using a sterile pipette, 1 drop each of the serially diluted soil-water solution was dropped into a sterile petri dish to which a freshly prepared sterile Potato Dextrose Agar (PDA) supplemented with a capsule of chloramphenicol (500mg BP to 500ml of freshly prepared sterile PDA) and 2 drops of lactic acids (to each Petri dish before it solidifies) was added. Afterwards, the plates were sealed with masking tape and incubated at a temperature of 28-31^OC for 48 hours or more depending on the rate of growth of each plate.

To obtain a pure culture of the fungi isolates, developing fungal cultures were aseptically sub-cultured into freshly prepared PDA plates and incubated until the fungus begins to sporulate followed by subsequent sub-culturing and incubation a number of times until pure cultures consisting of only one type of fungus was obtained. A part of the pure culture was then aseptically transferred into sterile agar slants which had been previously prepared in 14ml McCartney bottles. The bottles were then incubated till full growth of the fungus is observed and these served as stock cultures.

2.1.3 Identification of fungi isolated

To identify each of the fungus, a small portion of each pure isolate was teased with a sterile inoculating loop (the inoculating loop was sterilized by dipping in ethanol and flamed on spirit lamp) into 2 drops of lacto phenol in cotton-blue on a clean slide and a cover slip was placed on it. This was thereafter examined under a light microscope. Identification of fungus was done using morphological parameters (that is , the examination of the size, shape ,colour, spore formation and the number of days for the fungus to reach maximum diameter (9cm) of the Petri dish and the texture of fungal growth) as described by [13].

2.2 Mycofiltration Technique

The pure culture of each of the fungal species was removed from the sterile petri-dish and placed in the self-fabricated mycofilter (Plate 1), where each of the fungus acted as a mesh of some sort through which the effluent was to drain.

The freshly collected raw Industrial effluent samples were stored in a sterile sample bottle, after which each was poured separately into different mycofilters (which contained a pure culture each of *A. niger* and *A. flavus*) ensuring a free flow of the filtrate. The Industrial effluent poured thus passed through the first layer which performs the first filtration process, and then to the second and third layer, before it finally got to the filtrate collecting container (plate 1). This filtrate was re-introduced into the mycofilter three times to ensure proper filtration process. The control samples for this research were the raw unfiltered effluent samples. The final filtrate was then poured into a presterilized sample bottle which was then taken to the laboratory to determine some physicochemical parameters present before (Raw i.e. control) and after the filtration process (filtrate).

2.3.1 Chemical oxygen demand (COD)

The chemical oxygen demand (COD) of in samples was determined measuring 100ml of the sample and mixed with 5ml sulphuric acid (1:3). The mixture was heated quickly to the boiling point. Then 15ml of 0.01M potassium permanganate solution was immediately added into the boiling mixture and left for exactly 10min, and after which Oxalic acid (0.01M) solution was added. Thereafter, another 2- 3 drops of 0.01M potassium permanganate solution were added to the hot solution as necessary to a noticeable pink colour [14].

Calculation:

$$\text{COD (mg/l)} = \frac{\text{Value (obtained)} \times 0.316 \times 1000}{100}$$

2.3.2 Biological oxygen demand (BOD)

The Biological Oxygen Demand was determined as follows: two BOD bottles were filled with diluted effluent sample. The bottles were stopped tightly. One of the bottles was placed in the incubator at 20ºC. About 2ml of Manganese sulphate solution was added followed by 2ml alkali- iodide oxide reagent well below the surface of the liquid. The solution was mixed carefully. The precipitate was allowed to settle leaving a clear supernatant above the manganese hydroxide. It was shaken again. Two ml of concentrated H_2SO_4 was added by allowing the acid to run down the neck of the bottle. The bottle was re-stopped and mixed by gentle inversion until dissolution was complete. One hundred mililitres of sample were taken from the bottle and titrated with 0.025N sodium thiosulphate solution to a pale straw yellow. One ml of starch solution was added and the titration continued to the last appearance of the blue colour [14].

Fig. 1. Cartographic view of the point where soil for the isolation of fungi was picked

2.3.3 Chloride

The chloride in the samples was determined using the mercury nitrate method where 100ml of sample was placed in a 250ml conical flask and 1ml of bromophenol blue indicator

solution was added, and the solution was titrated with 0.014N of Mercuric nitrate ($AgNO_3$) until the first time that the blue which appeared did not disappear on shaking of solution [15].

Fig. 2. Cartographic view of the point of collection of the effluent sample

Amount of chloride present in each sample was derived thus:

$$Chloride_{(mg/l)} = \frac{A \times N \times D \times 1000}{\text{Volume of sample}}$$

Where,

A = Titration value
N = Normality of $AgNO_3$
D = Dilution factor

2.3.4 Sulphate

The sulphate concentration was determined using the Gravimetric method:-

The water sample was filtered and to 200ml of filtrate in a 400ml beaker, was added 5ml of dilute HCl (2M) acid. The liquid was raised to boiling at 160ºC and then 10ml of 10% $BaCl_2$ was added, and allowed to stand for 30min. The solution was filtered using Whatman No.1 filter paper, the filter paper washed until free of excess barium chloride while the precipitate was washed and weighed as $BaSO_4$. From this weight, the weight of sulphate was calculated as follows [16,15].

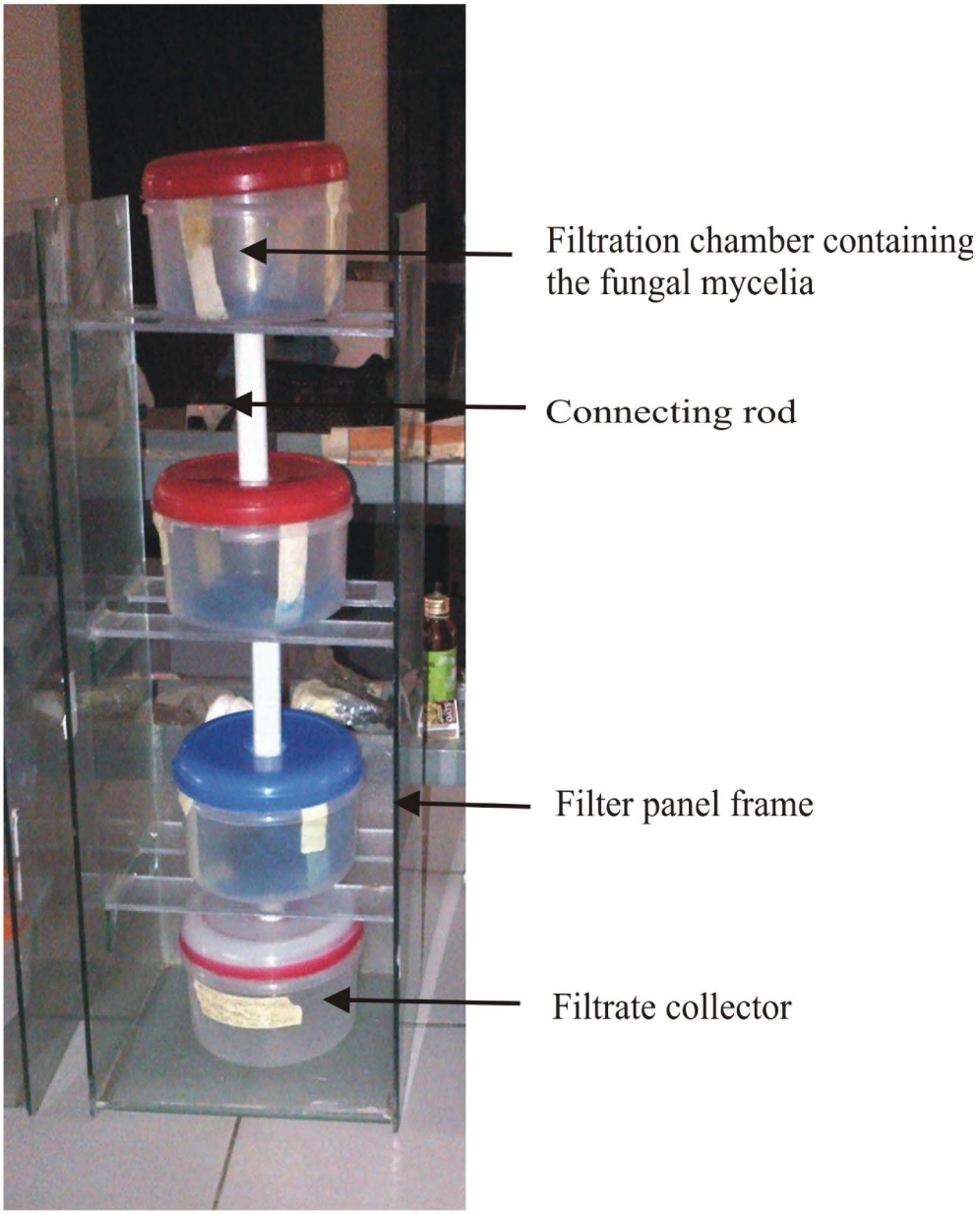

Plate 1. Picture showing the complete filtration apparatus

Calculation:

$$SO_4 \text{ (mg/l)} = \frac{\text{weight of } BaSO_4 \times 412}{\text{Volume of sample}}$$

2.3.5 Heavy metal and mineral analysis in samples

The above mineral contents were determined using the method described below:

Five millilitres (5.0ml) of samples were measured into a 250ml beaker and solubilized with 30ml of concentrated trioxonitrate (V) acid (HNO_3) evaporated to dryness on hot-plate magnetic stirrer (Model: STUART SCIENTIFIC U.K), and the residue was further heated for about 30min. Thereafter, the sample was dissolved in 40ml of hydrochloric acid (HCl) and digested for about 2 hours on hot-plate magnetic stirrer. One mililitre of diluted hydrochloric acid solution was further added to the sample and boiled for about 1 hour. This was filtered while hot using Whatman NO. 4 filter paper, and washed with HCl solution and the volume made up to 100ml with distilled water.

The elements Ca, K, Zn, Pb, Fe etc. were determined using Spectrometry method by means of the Atomic Absorption Spectrophotometer (the AAS-Model used was Phillip PU 9100X) with a hollow cathode lamp and a fuel rich flame (air-acetylene). Samples and standard were aspirated and the mean signal responses were recorded at the elements respective wavelength.

2.3.6 Total acidity

The total acidity was measured by adding 0.1 ml (2 drops) of methyl orange indicator to 50ml of the sample in a conical flask. It was then titrated with standard 0.02N NaOH until the colour changed to the faint orange characteristics of pH 4.5. [15,16]. Total acidity was thereafter calculated thus.

$$\text{Acidity as mg/l } CaCO_3 = \frac{A \times N \times 5000 \times D}{\text{Volume of sample}}$$

Where,

A = Titration for sample
N = Normality of NaOH
D = Dilution factor

2.3.7 Total alkalinity

The total alkalinity was measured by adding 0.1 ml phenolphthalein indicator to 50ml of sample in a conical flask. It was then titrated with standard 0.02N HCl to pink colouration [15,16].

$$\text{Total Alkalinity} = \frac{A \times N \times 5000 \times D}{\text{Volume of sample}}$$

Where,

D = Dilution Factor
N = Normality of HCl (0.02N)
A = Titre value

2.3.8 Determination of total hardness

Fifty mililitres of sample were added to 4 to 6 drops of Erico Chrome indicator solution. Ten mililitres of buffer solution was added, mixed and then titrated with the standard Ethylenediaminetetraacetic acid (EDTA) solution [16].

$$\text{Total Hardness (as } CaCO_3\text{ (mg/l)} = \frac{1000 \times \text{volume of EDTA}}{\text{Volume of sample}}$$

2.3.9 pH value

Ten millilitres of sample was measured into a 100ml beaker and the pH was determined with the aid of a previously standardized pH meter electrode (Model: Hanna P^{211} Microprocessor) using pH 4 and 7 buffers. The electrode was transferred by dipping into the sample (filtrates), and the corresponding value recorded.

2.3.10 Electrical Conductivity (EC)

This was determined using a conductivity meter (MODEL ADWA AD 1000) with a known cell constant and conductivity cell. The cell constant of the meter was 1.2 S/m. The cell was rinsed with the water sample three times and the temperature was adjusted to 25.0ºC±0.1ºC. After this standardization procedure on the meter, the conductivity of each effluent sample was then taken using the meter as described by 14.

2.3.11 Total dissolved solids (TDS)

A modified approach of [14] was adopted. One glass fibre filter disc was placed on its holder and thereafter washed three times. A clean evaporated dish was heated at 105ºC and cooled for one hour. One hundred and fifty millilitres of water sample were filtered through the glass fiber filter, while 100ml of the filtered sample was transferred to the preweighed evaporating dish. This was evaporated on a steam bath and then dried for about 60 minutes in an oven, cooled and thereafter placed in a desiccator. The steps were repeated until a constant weight was obtained.

2.3.12 Total Suspended Solids (TSS)

A modified approach of [16] was adopted where suspended solids were determined by placing a pre-weighed Whatman No. 1 filter paper on a holder and washed with 3 x 20ml water. One hundred mililitres of water samples were filtered through the filter paper. The filter paper was carefully removed and dried for about one hour at 105ºC, cooled in a desiccator and then weighed. Steps were repeated until a constant mass was obtained. TSS was calculated thus:

$$\text{Total Suspended Solids (TSS) in (mg/l)} = \frac{\text{Mass of solids of filter (mg)} \times 1000}{\text{Volume of sample filtered (litre)}}$$

2.4 Treatments

In all, a total of 3 treatments for each of the sample as indicated below were used in this experiment.

Treatment A = Untreated effluent (Control)
Treatment C = Effluent filtered using *A. niger*
Treatment E = Effluent filtered using *A. flavus*

2.5 Statistical Analysis of Data

The data obtained from the laboratory were analyzed using IBM SPSS version 20.0 and Microsoft Office Excel 2010. The data were subjected to a one way analysis of variance – ANOVA. The separation of the means (post Hoc Test) was done using the independent sample T-Test at 1% level of significance. In all cases, the value for each data was the mean from 3 replicates.

3. RESULTS

3.1 Isolation and Identification of Fungal Samples

The results of the Isolation Studies showed most of the fungi encountered from the soil at this dumpsite as belonging to the genus *Aspergillus*, essentially *A. niger* (Plates 2A and 2B) and *A. flavus* (Plates 3A and 3B).

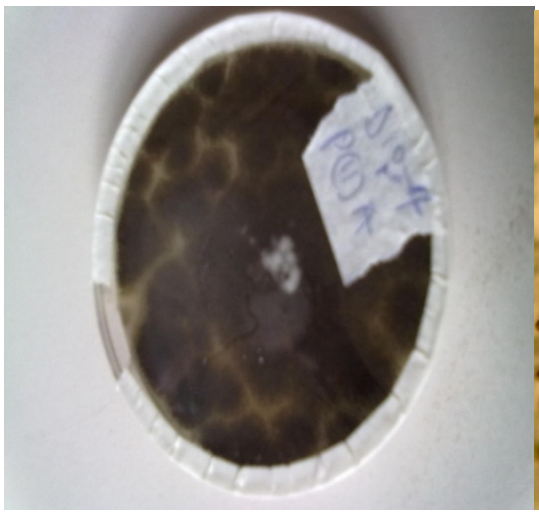

Plate 2A: Plate showing a culture of *A. niger* X 0.5

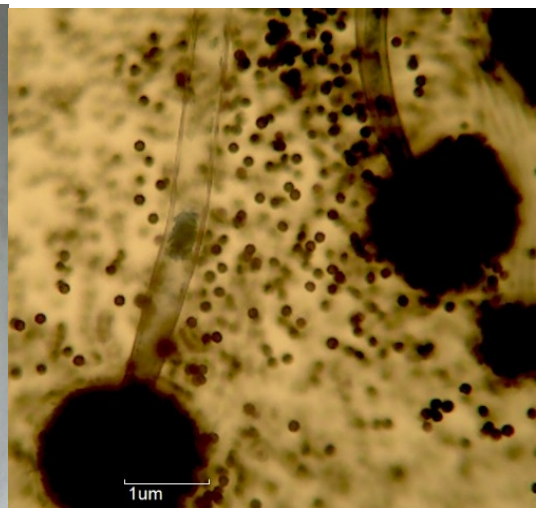

Plate 2B: Photomicrograph of *A. niger* X120

3.2 Chemical Parameters for Effluent Sample

3.2.1 Chemical oxygen demand (cod) mg/l

The results of the chemical parameters in the effluent samples as presented in Fig. 3A shows that the highest mean value of 277.03 for the COD was found in Treatment A

{untreated (control) effluent}, a value that was significantly higher (p≤0.01) than the value obtained for Treatment C (233.83) i.e. effluent filtered using *A. niger*. The value of COD recorded for Treatment E (215.93) i.e. effluent filtered using *A. flavus* however was significantly lower (p≤0.01) than the values obtained for both Treatments A and C.

Plate 3A: Plate showing a culture of *A. flavus* X 0.5

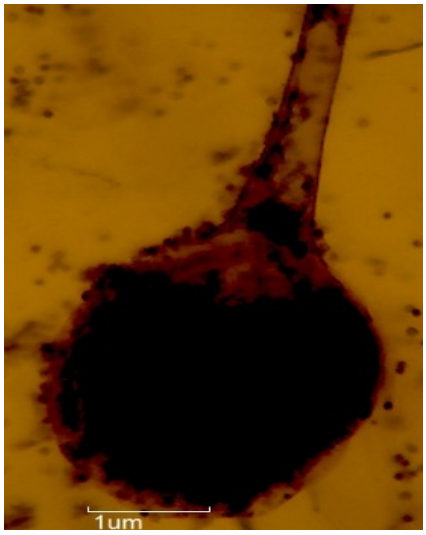

Plate 3B: Photomicrograph of *A. flavus* X120

3.2.2 Biological oxygen demand (bod) mg/l

The results as presented in Fig. 3A shows that the mean value of BOD for Treatments A, C and E were 52.72, 38.16 and 36.42 respectively. There was a significant difference (p≤0.01) amongst these values recorded for each of the Treatments.

3.2.3nitrate (mg/l)

The highest mean value for Nitrate (as shown in Fig. 3A) was found in Treatment A (33.5833). The value of nitrate in Treatment A was significantly higher (p≤0.01) than the mean values for nitrate in Treatments C and E (28.90 and 26.31 respectively). Similarly, the mean value of Nitrate for Treatment C was significantly higher (p≤0.01) than the value obtained for Treatment E (Fig. 1a).

3.2.4 Sulphate (mg/l)

Fig. 3A show that the highest mean value for Sulphate was found in Treatment A (29.57) i.e. unfiltered effluent (Control). Treatments C and E had mean values of 16.21 and 14.01 respectively. There was a significant difference (p≤0.01) in the mean values for all the different Treatments.

3.2.5.1 Calcium (Mg/l)

The results in Fig. 3A equally show that the mean value of Calcium in Treatments A, E and C were 23.50, 19.04, and 16.72 respectively. There was a significant difference (p≤0.01) amongst the mean values for calcium in the different Treatment samples.

3.2.5.2 Chloride (Mg/l)

The mean value for chloride as presented in Fig. 3A for Treatments A, C and E was 56.49, 44.56 and 32.97 respectively. Similarly, there was a significant difference ($p \leq 0.01$) amongst the mean values of Chloride for each of the Treatments.

3.2.5.3 Potassium (Mg/l)

The results presented in Fig. 3A show that Treatment A had the highest mean value for Potassium (14.3400). This value was significantly higher ($p \leq 0.01$) than the mean values for Treatments C (10.89) and E (9.68). There was equally a significant difference ($p \leq 0.01$) between the mean values for potassium in Treatments C and E.

3.2.5.4 Iron (Mg/l)

The results as presented in Fig. 3B show that the highest mean value recorded for this element was found in Treatment A (2.59) i.e. unfiltered control effluent, a value that was significantly higher ($p \leq 0.01$) than the value recorded for Treatment C (2.45) i.e. effluent filtered using *A. niger.* In addition, the value of Iron recorded for Treatment C was not significantly different from what was obtained for Treatment E (2.41) i.e. effluent filtered using *A. flavus*.

3.2.5.5 Zinc (Mg/l)

The results for this element as presented in Fig. 3B show that the highest mean value was found in the Control samples - Treatment A (0.46). This value obtained for Treatment A (Control) was significantly higher ($p \leq 0.01$) than the mean values obtained for Treatment C (0.34) and Treatment E (0.14). In a similar vein, there was a significant difference ($p \leq 0.01$) between the mean values for Zinc in both Treatments C and E.

3.2.5.6 Chromium (Mg/l)

The results obtained for Chromium in the effluent samples as shown in Fig. 3B indicated that the highest mean value of 0.414mg/l was found in Treatment A, a value that was significantly higher ($p \leq 0.01$) than what was found in Treatments C (0.07mg/l) and E (0.013mg/l). However, there was no significant difference ($p \leq 0.01$) between the mean value of Chromium for Treatments E and C.

3.3 Physical Parameters for Effluent Sample

3.3.1 Total acidity

The results as presented in Fig. 4A show that the highest mean value for Total Acidity in the effluent was found in Treatment E (76.00), a value that was significantly higher ($P \leq 0.01$) than the mean value for Treatment C (66.00). In a similar vein, the mean value for Treatment A (48.00) i.e. untreated (control) effluent sample was significantly lower ($P \leq 0.01$) than the mean values obtained for both Treatments E and C.

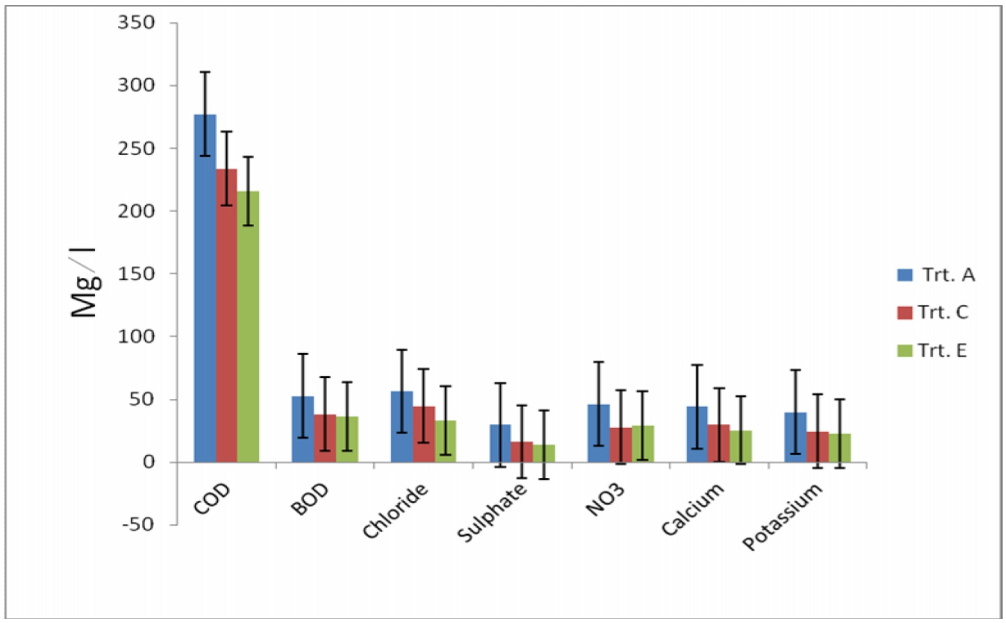

Fig. 3a. Values for some chemical parameters in effluent samples

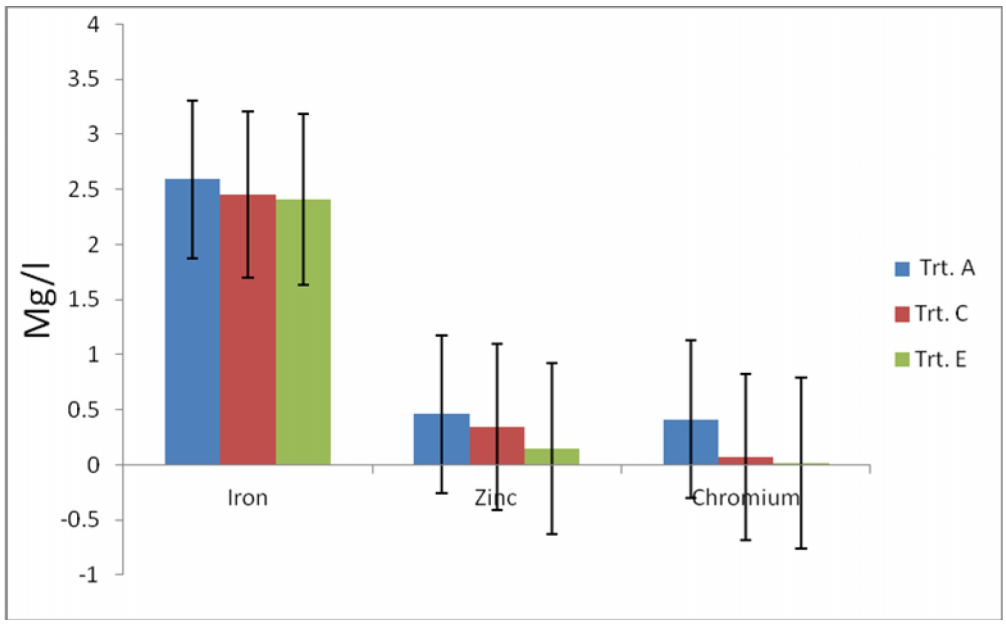

Fig. 3b. Values for some chemical parameters in effluent samples

3.3.2 Alkalinity

The highest mean value of 204.00 for this parameter was found in Treatment A (i.e. Control), followed by Treatment C with a mean value of 164.00 while the lowest mean value of 112.66

was recorded for Treatment E. There was a significant difference (P≤0.01) amongst all the mean values –Fig. 4A.

3.3.3 Hardness

The results for this parameter as presented in Fig. 4A show that the highest mean value (56.00) for hardness was found in Treatment A - Control Samples, While the value for Treatment C (45.33) was significantly lower (P≤0.01) than the value recorded for Treatment A, it was significantly higher (P≤0.01) than the value obtained for Treatment E (41.33) which was the lowest mean value recorded for this parameter.

3.3.4 pH (at 25ºC)

The results shown in Fig. 4A reveals that the highest mean value for the pH was found in Treatment A effluent samples (7.03), a value that was significantly higher (P≤0.01) than the mean value found in Treatment E (6.62). On its own, the mean value for Treatment E was not significantly lower (P≤0.01) than the mean values obtained for Treatment C (6.67).

3.3.5 Electrical conductivity (E.C.)

The highest value for E.C. recorded was for Treatment C (as shown in Fig. 4A) at 13.36, a value that was significantly higher (P≤0.01) than the lowest mean value obtained, which was for Treatment A (6.3). The mean value of E.C. recorded for Treatment E (7.56) was equally significantly lower (P≤0.01) than what was obtained for the control samples of Treatment A (6.3000).

3.3.6 Total dissolved solid (tds) mg/l

The results of the physical parameters in the effluent sample (Fig. 4B) shows that the highest value of Total Dissolved Solid recorded in this work was found in Treatment A (640.00) i.e. control sample; this value was significantly higher (p≤0.01) than the value found in Treatment C (420.00) i.e. effluent filtered with *A. niger*. In addition, the value of Total Dissolved Solid recorded for Treatment C (420.00) was equally significantly higher (p≤0.01) than what was obtained for Treatment E (240.0000) i.e. effluent filtered with *A. flavus*.

3.3.7 Total suspended solid (tss) litre

The results of the physical parameters in the effluent sample (Fig. 4B) shows that the highest value of Total Suspended Solid was found in Treatment A (513.33), a value that was significantly higher (p≤0.01) than the value found in Treatment C (320.00). In addition, the value of Total Suspended Solid recorded for Treatment C (320.00) was equally significantly higher than what was obtained for Treatment E (206.6667).

3.3.8 Total solid (TS)

The results of the physical parameters in the effluent sample (Fig. 4B) shows that the highest value of Total Solid recorded in this work was found in Treatment A (1153.33), a value that was significantly higher (p≤0.01) than the value found in Treatment E (740). In addition, the value of Total Solid recorded for Treatment E (740) was equally significantly higher (p≤0.01) than what was obtained for Treatment C (446.66).

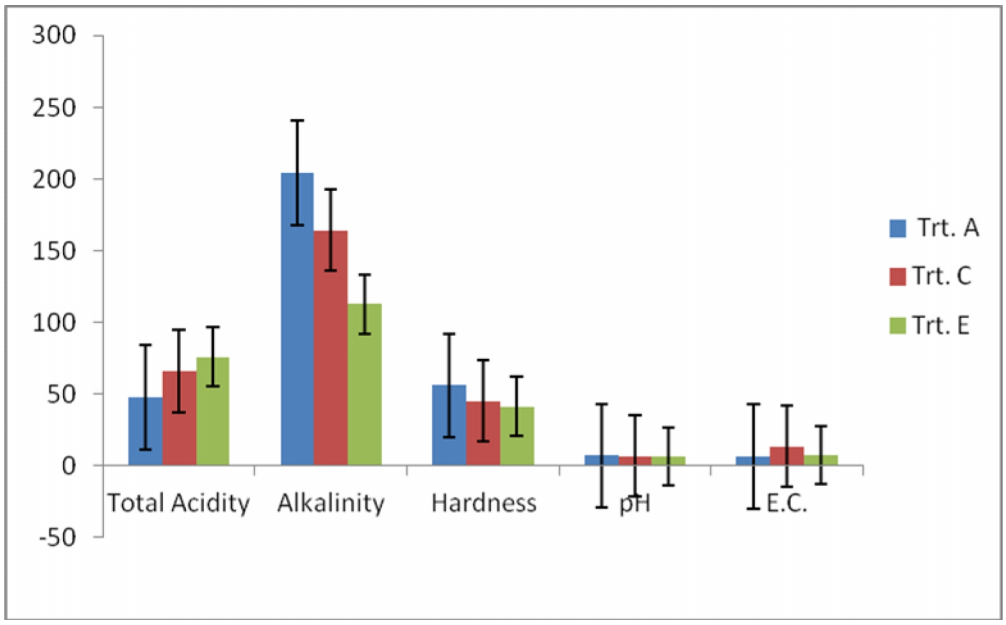

Fig. 4A. Values for some Physical parameters in effluent samples

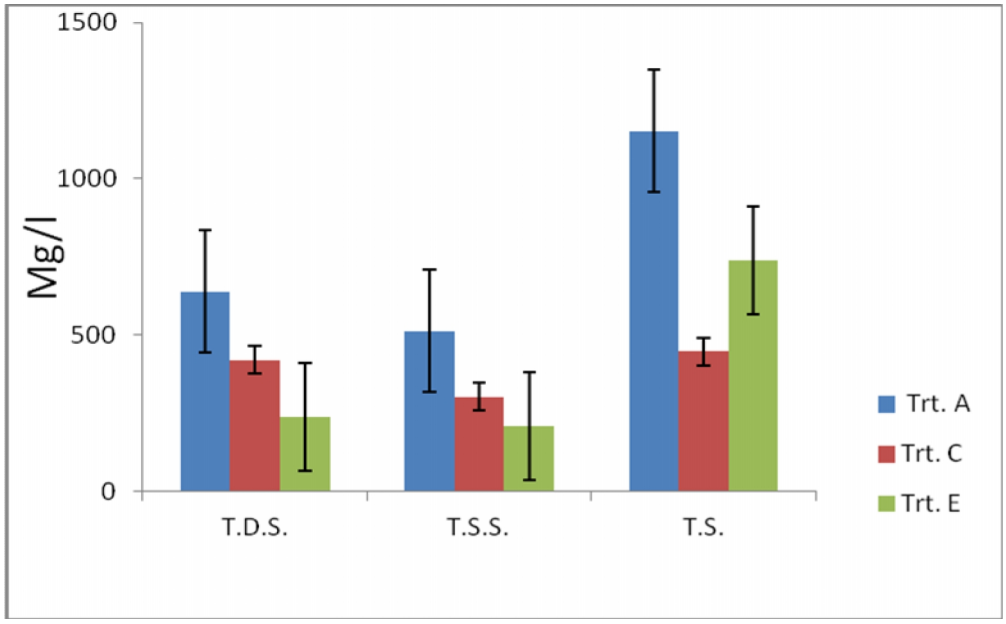

Fig. 4B. Values for some Physical parameters in effluent samples

4. DISCUSSION

Water pollution by effluent has become a question of considerable public and scientific concern in the light of established evidences of their extreme toxicity to human health and to

the ecosystems [17]. The occurrence of heavy metals in industrial effluents constitutes a major source of the heavy metals entering aquatic media [17]. There is therefore the need for a regular assessment of these Industrial effluents as a way of reducing environmental pollution (and its attendant negative consequences) to a minimum. The physiochemical characteristic of water is an important determinant of the wholesomeness of any aquatic system. It should be noted that these physicochemical indices are greatly influenced by a number of factors such as climatic, vegetation, edaphic and the geological nature of the bed of any water body.

The mean value of the chemical and physical parameters in this Industrial effluent was compared with standards provided by the now defunct FEPA (Federal Environmental Protection Agency) and LASEPA (Lagos State Environmental Protection Agency).

An indication of organic oxygen demand content of wastewater can be obtained by measuring the amount of oxygen required for its stabilization either as BOD and or COD [17]. A general trend in the results from this experiment showed that filtering the effluent samples through the fungi mycelia caused a significant improvement in the physicochemical indicators of the effluent (when compared to the unfiltered control samples in Treatment A). Another obvious trend from the results was that *A. flavus* generally recorded a significantly higher improvement over *A. niger* for most of the physicochemical indicators measured in the effluent Samples.

The values for the BOD in the 2 mycofiltered effluent samples were found to be below the FEPA and LASEPA standards of 50mg/l and 30mg/l respectively [18,19]. The filtering of the effluent samples using each of the fungal mycelia thus achieved a significant reduction in the level of this parameter (and consequently a significant reduction in the amount of biodegradable pollutants) when compared to the untreated effluent sample (Treatment A). A high BOD has undesirable consequence on aquatic life, such as the production of ammonia and hydrogen sulphide [20] which affect fish negatively in various ways. The biodegradation of organic materials thus exerts oxygen tension in the water and increases its BOD.

Although both fungi were able to achieve a significant reduction in the amount of COD of the effluent sample (when compared to the raw unfiltered Treatment A), the values were nevertheless higher than the FEPA and LASEPA standards of 150mg/l and 60mg/l respectively [18,19]. The results showed an excessively high COD value in the initial (untreated) effluent sample i.e. Treatment A, thereby suggesting that the Industry considered in the present study like a number of industries in Nigeria probably did not treat their effluent before discharging same into the environment, a position which had been alluded to in this regard by some earlier reports [21,22,23].

The most highly oxidized form of nitrogen compounds is commonly present in surface and groundwater because it is the end product of aerobic decomposition of organic nitrogenous matter. Unpolluted natural waters usually contain only minute amounts of nitrate (Jaji et al. [20]). In this research, the nitrate concentrations in all the effluent samples were higher than the 20mg/l and 10mg/l standards specified by FEPA [18] and LASEPA [19] respectively. Nitrate in water over 10mg/l may cause blue baby disease, particularly in infants of 1 to 6 months of age [24]. Nitrate forms nitrosamine in stomach which causes gastric cancer.
The range of the values for chloride observed in all the effluent samples was low compared to the maximum permissible limit of 600mg/l stipulated by FEPA [18].

Alkalinity of any water is defined as its ability to neutralize acid [25]. If alkalinity value in drinking water is high, the taste of the water becomes unpleasant, and its feel slippery [26]. In the effluent samples, total alkalinity was from 112 to 350 mg/l. Thus, all the samples were in the prescribed tolerance limit (200-600 mg/l) of FEPA standards. Notwithstanding the above, results from this experiment shows that filtration of the effluent samples using each of the fungal species caused a significant reduction in the alkalinity levels of the effluent sample. Highly alkaline waters (>200) and a pH >7.0 can cause drying of the skin. In addition, alkalinity is important for aquatic life because it buffers against rapid changes in pH and thereby makes water less vulnerable to acid rain [26].

Hardness of natural waters is caused largely by calcium and magnesium salts and to a small extent by iron, aluminum, and other metals. Water hardness is important to fish culture and this is because calcium plays some important roles in the biological processes of fish such as bone formation, blood clotting and other metabolic activities [27]. Although all the values recorded for hardness in each of the effluent samples were below the maximum limit of 100mg/l stipulated by FEPA [18], filtration of the effluent using each of the fungal samples nevertheless resulted in a significant reduction in the hardness of this effluent sample.

The mean pH values in the effluent samples fell within the range of 6.0 – 9.0 recommended by FEPA [18] as well between 6.5 – 8.8 range recommended by LASEPA [19]. The mycofiltered effluent samples however were slightly more acidic than the Control (unfiltered) effluent sample. This probably can be adduced to the fact that the media (PDA) used in growing the fungi was made acidic (pH 4.8) by the addition of lactic acid (so as to discourage the growth of bacteria on same).

5. CONCLUSION

A Study of the physical and chemical characteristics of water provides a good insight into the quality of a water body. The results from the present studies show that the unfiltered (Control) effluent samples are polluted as they contain significantly higher levels of some important chemical indicators such as nitrates, phosphates, chlorides and sulphates, compared to the mycofiltered samples. Filtering the Control effluent sample through each of the fungal mycelia used in this research in turn caused a significant improvement in most of the parameters investigated. This thus shows the ability of *A. niger* and *A. flavus* (that were used in this experiment) to clean up some important physicochemical indicators of water pollution.

As industries draw out plans for their establishment and development, there is need for the incorporation of proper wastewater management strategies and policies into these plans to take care of its wastewater production. Also proper wastewater analysis and treatment should be done on industrial wastewater before final discharge into the environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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