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Investigation into the Use of Urea and NPK Fertilizers in the Bioremediation of Domestic Wastewater

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ABSTRACT: The use of urea and NPK 15:15:15 fertilisers as nutrient sources for microbes in the bioremediation of domestic wastewater was studied in a batch system. Five samples of domestic wastewater supplemented with 10, 20, 40, 60 and 80 g/L of urea, NPK as well as a combination of both fertilisers and the control were monitored for a period of 5 weeks. Physicochemical properties such as, Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO) and pH were measured. The results obtained showed that there was a reduction in BOD from 120.34 to 16.10 mg/L, 120.34 17.76 mg/L and 120.34 to 15.83 mg/L for wastewater treated with urea, NPK and a combination of both respectively. There was an improvement in the DO level from an initial value of 0.8 mg/L to 3.4, 3.2 and 3.6 mg/L respectively for wastewater treated with urea, NPK and a combination of both respectively. Generally, the best performance resulted when both fertilisers were used together. The values obtained were all within the acceptable limits set by the Federal Environmental Protection Agency (FEPA).
***Keywords*:** Bioremediation, domestic wastewater, urea, NPK, biochemical oxygen demand, Dissolved Oxygen

INTRODUCTION

There are thousands of restaurants and fast-food shops in Nigeria and they use over a million tons of water everyday. The direct discharge of wastewater generated from these restaurants and shops down the drain without treatment represents a huge environmental burden. The major effect of the improper disposal of untreated wastewater (especially those containing nitrates and phosphates) into natural water bodies is eutrophication (Godos et al, 2009; Munoz and Guieysse, 2008; Mulbry et al, 2008). In addition, the release of untreated wastewater leads to the accumulation of toxic products in the receiving water bodies with potentially serious consequences on the immediate ecological environment (Beg *et al,* 2003; Otokunefor and Obiukwu 2010).

Treatment of wastewater is currently carried out by a host of physical and chemical methods which are often costly and inefficient. For the past decade, a lot of attention has been given to the use of bioremediation as a means of treating wastewater and other effluents. It is seen as an effective and environmentally friendly treatment option for wastewater (Otokunefor and Obiukwu, 2010). Bioremediation involves the breakdown of complex organic molecules through biostimulation and bioaugmentation into simpler substances such as fatty acids, carbon dioxide and water (Agbor et al, 2012). Previous works done on the bioremediation of contaminated wastewater focused on natural attenuation, biostimulation and bioaugmentation with varying degrees of success recorded. Obahiagbon and Aluyor (2009) studied the potential use of inorganic nutrient (sodium nitrate and sodium nitrite) for the biostimulation of *Aspergilllus niger* for the bioremediation of petroleum hydrocarbon polluted water. Kim *et al.*, (2005) reported enhanced bioremediation rates of crude oil contaminated sand as a result of addition of inorganic nutrients. Agbor et al (2012) applied cocoa pod husk and plantain peels for the biostimulation of microbes during the biodegradation of crude oil polluted soil. Chikere et al (2009) and Ebere et al, (2011) reported on the effectiveness of poultry droppings in enhancing the degradation of crude oil polluted soil in Southeastern Nigeria. One common feature of these studies is that the addition of nutrients is necessary to enhance biodegradation of contaminated wastewater (Okoh, 2006).

Hence the aim of this study is to examine the potential applicability of inorganic fertilizers urea and NPK 15:15:15 for the biostimulation of indigenous microorganisms for the purpose of treating domestic wastewater.

MATERIALS AND METHODS

Sample collection and preparation

The domestic wastewater used for this study was obtained from fast food outlet at the city centre in Benin City, Edo State, Nigeria. Wastewater samples were collected in plastic containers previously cleaned by washing in non-ionic detergent, rinsed with tap water and later soaked in 10% HNO_3 for 24 hours and finally rinsed with deionised water prior to usage. The wastewater was collected at source to prevent any form of foreign contamination not associated with the process from which it was obtained. The wastewater was dispensed in 500mL quantities into six sets of 1000mL beakers. Beakers in each experimental set were then supplemented with different levels (5, 10, 20, 30, and 40 g/L) of nutrient sources urea and NPK 15:15:15 fertilizer as well as a combination of both in the ratio 1:1. A control experiment which did not contain any nutrient supplements was set up to serve as comparison between biostimulation and natural attenuation (bioremediation) to determine the effectiveness of the nutrient supplements in treating domestic wastewater.

Analyses

The physicochemical properties of the wastewater were monitored in the course of the remediation process. The following parameters; pH, BOD, DO and turbidity were monitored weekly for a period of 5 weeks. Sampling was done on day zero (before biostimulation) and subsequently at intervals of seven days (one week).

pH measurement

The pH of the wastewater was measured using an electronic pH meter (Fisher Accruement pH meter). The pH meter was calibrated using buffer solutions (pH 4 and 7). The temperatures of the buffer solutions and sample were taken using a thermometer and the temperature manually compensated for in the meter. After calibration, the sample was thoroughly mixed together using a stirrer and its pH was recorded while ensuring that the meter was rinsed with distilled water before and after each run.

Biochemical oxygen demand (BOD)

The azide modified winkler method was used in the estimation of the BOD of the wastewater samples. Four 300mL glass stoppered BOD bottles (two for the sample and two for the blank) were used for the procedure. To two of the BOD bottles was added 10mL of the wastewater sample and the remaining volume was filled with dilution water. Dilution water was added to the remaining two BOD bottles to be used as blank. Two BOD bottles, each containing the wastewater sample solution and blank solution respectively were preserved in a BOD incubator at 20^oC for five days. The remaining two bottles also containing the wastewater sample solution and blank solution respectively were immediately analysed. 2mL each of manganese sulphate and alkali-iodide-azide reagent were added sequentially to the BOD bottle and it was allowed sufficient time for complete reaction with oxygen. The precipitant formed was dissolved with 2 mL of concentrated sulphuric acid to form a golden brown solution. 100 ml of the resulting solution was poured into 250 ml flask and 3 drops of starch indicator were added and titrated against 0.1 N sodium thiosulphate ($Na_2S_2O_4$) initial blue black coloration. The volume of 0.1 N ($Na_2S_2O_4$) solution used was recorded as it corresponds to the DO in mg/L. At the end of 5 days, the procedure outline in the foregoing was repeated and the volume of 0.1 N $Na_2S_2O_4$ used was recorded also to indicate the DO in mg/L. The BOD of the sample was calculated as follows:

$$BOD_5 = \frac{(DO_O - DO_5)}{p} \quad (1)$$

Where DO_o= Dissolved oxygen concentration at zero time

DO_5= Dissolved oxygen concentration after 5 days of incubation

p= Dilution factor

Dissolved Oxygen (DO)

In situ determination of dissolved oxygen of the wastewater sample was done using a dissolved oxygen meter which was calibrated prior to measurement with the appropriate traceable calibration solution (5%HCl) in accordance with the manufacturer's instruction. The meter was first zeroed and subsequently inserted into the wastewater sample and the reading then recorded.

RESULTS AND DISCUSSION

The profiles of the BOD of the wastewater at various concentrations of urea, NPK and a combination of both fertilisers are shown in Figures 1 to 3 respectively. The general trend observed for all three Figures indicate that the BOD of the wastewater decreased with increase the concentration of the stimulants both at the start and at

the end of bioremediation. At a concentration of 0 g/L (no biostimulant added) there was still an observable reduction (though not significant) in the BOD of the wastewater with time. The reduction in BOD could be attributed to the activities of the indigenous microbes present in the wastewater which converts the contaminants into less toxic substances such as CO_2, H_2O and many intermediates like organic acids, lipids, esters, complex alcohols and microbial proteins in form of enzymes (Obahiagbon and Aluyor, 2009). Higher reductions in BOD were recorded when stimulants were added indicating that the biodegrading ability of the indigenous microorganism had been enhanced. The BOD was reduced from 120.34 to 16.10 mg/L, 120.34 17.76 mg/L and 120.34 to 15.83 mg/L corresponding to 86.62, 85.24 and 86.85% removal efficiencies for wastewater treated with urea, NPK and a combination of both respectively as shown in Figures 1 to 3. Similar results were reported by Satyawali and Balakrishnan, (2008) for the treatment of wastewater from molasses-based alcohol distilleries. The better performance observed for urea relative to NPK can be explained by noting that biodegrading microorganisms need oxygen, carbon and hydrogen to function optimally. These are present in urea fertiliser and not in NPK fertiliser. It also stands to reason that the best result was obtained when both fertilisers were combined as the medium then contained all necessary nutrient needed by the microbes as shown in Figure 3. These values fell below the maximum value of 30 mg/L stipulated by FEPA.

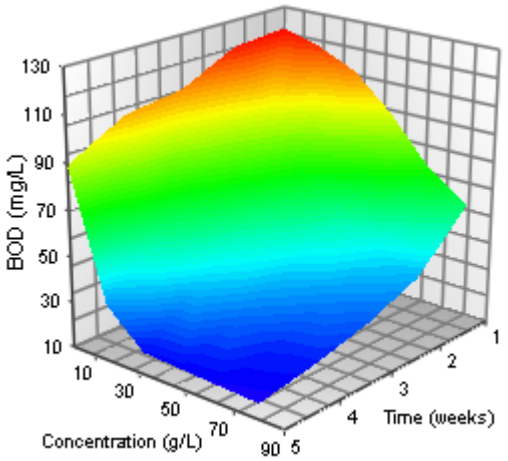

Figure 1. Variation of BOD with time for wastewater remediated with urea fertiliser

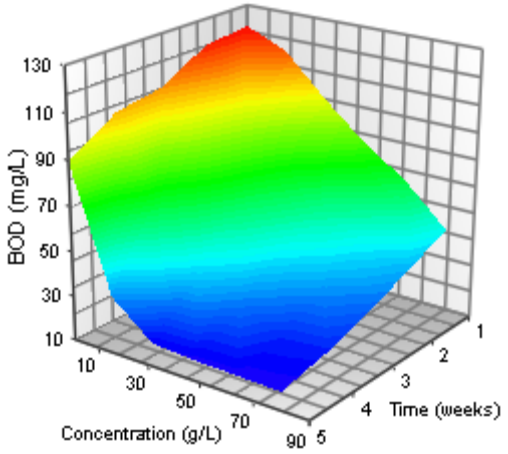

Figure 2. Variation of BOD with time for wastewater remediated with NPK fertiliser

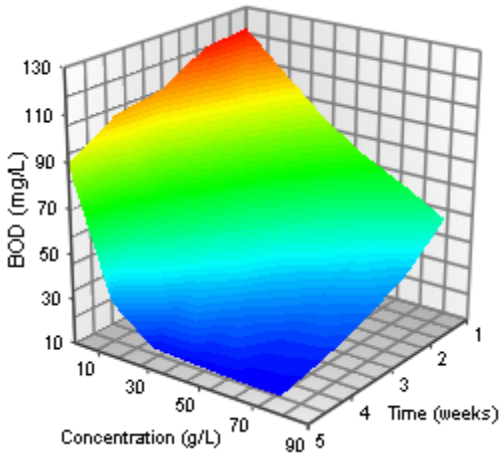

Figure 3. Variation of BOD with time for wastewater remediated with both urea and NPK fertiliser

Figures 4 to 6 show the variation of the dissolved oxygen (DO) content of the wastewater with time at various concentrations of fertiliser. The trend evident from the Figures indicate that there was a positive correlation between the DO and the concentration of fertilisers used suggesting that increasing the dose of fertilisers enhanced the bioremediation ability of the indigenous microbes in the wastewater. The increase in the DO corresponds to the decrease in BOD of the wastewater as indicated in Figures 1 to 3. The increase in DO level is an indication of the occurrence of bioremediation (Droste 1997).

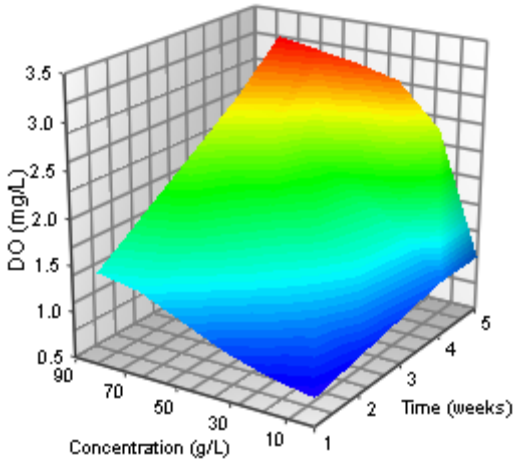

Figure 4. Variation of DO with time for wastewater remediated with urea fertiliser

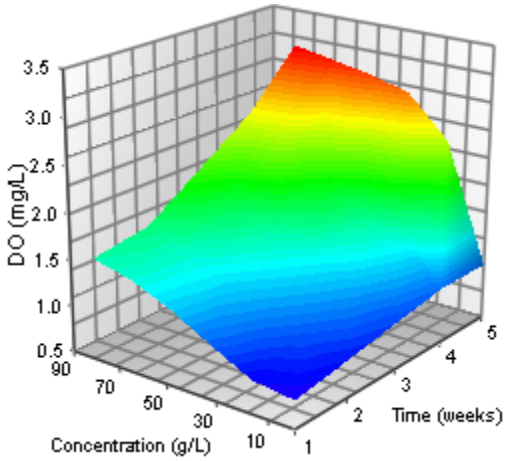

Figure 5. Variation of DOwith time for wastewater remediated with NPK fertiliser

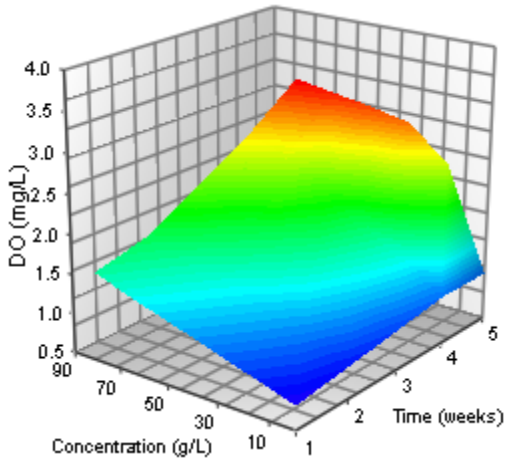

Figure 6. Variation of DO with time for wastewater remediated with both urea and NPK fertiliser

Although the initial DO of the wastewater (0.8mg/L) was far below the limit of 2.0 mg/L set by FEPA, the indigenous microbes upon stimulation by the fertilisers were able to improve DO level to 3.4, 3.2 and 3.6 mg/L respectively for biostimulation with urea, NPK and a combination of both respectively. These results again show that using a combination of both fertilisers led to the best degradation efficiency of the indigenous microbes.

Figures 7 to 9 show the variation of the pH of the wastewater with time in the course of bioremediation. The indigenous microbes responsible for the bioremediation process were biostimulated with urea fertiliser, NPK 15:15:15 fertiliser and a combination of both as shown in Figures 7, 8 and 9 respectively.

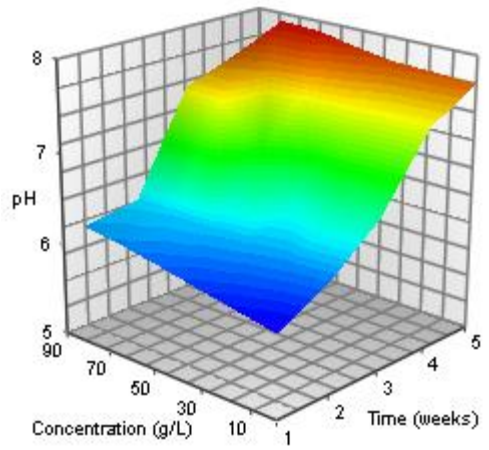

Figure 7. Variation of pH with time for wastewater remediated with urea fertiliser

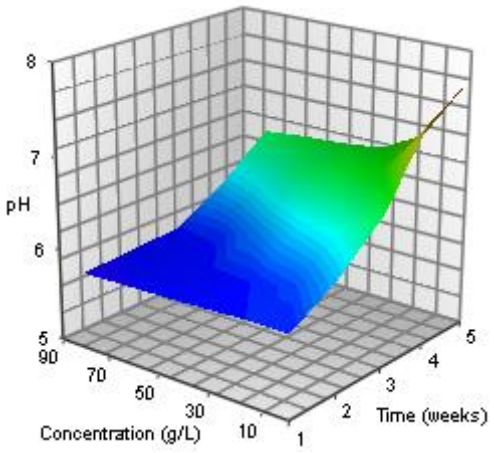

Figure 8. Variation of pH with time for wastewater remediated with NPK fertiliser

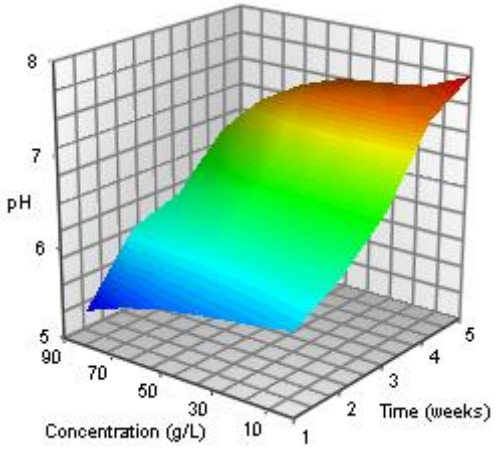

Figure 9. Variation of pH with time for wastewater remediated with both urea and NPK fertiliser

The Figures displays the effect of the interaction between the concentration of biostimulant (fertilisers) and remediation time on the pH of the wastewater as it undergoes bioremediation. The general trend observed indicates that the pH of the wastewater increased with increase in bioremediation time. The initial pH of the sample was 5.9 indicating slight acidity. This might be as a result of the type of the type of food substances prepared in the fast food outlets which are mainly vegetables, carbohydrates, proteins as well as fats and oils and consequently these will require an acid detergent for cleaning. Acid detergents are used mainly for protein, mineral and vegetable deposit removal and typically contain phosphoric acid (Zhao et al, 2006).

It can be observed from Figure 7 that at the start of bioremediation, the pH of the wastewater increased with increase in the concentration of urea fertiliser. The same trend was also observed at the end of the remediation process. This may be as a result of the fact that urea is basic in solution and action. However a different trend was observed for the wastewater remediated with NPK fertiliser as shown in Figure 8. The pH decreased with increase in the concentration of NPK fertiliser indicating that NPK might be slightly acidic in action. For the wastewater remediated with both urea and NPK fertiliser (Figure 9), a trend similar to that of Figure 8 was observed. The pH values recorded for all the treatment methods were within the range (6-9) set by the Federal Environmental Protection Agency (FEPA, 1997).

CONCLUSIONS

The potential use of urea and NPK fertilizers as stimulants of indigenous microbes in the bioremediation of domestic wastewater was investigated in this study. The following conclusions can be drawn.

The wastewater used for the study contained some indigenous microbes as seen in the response to key indicators of the degree of bioremediation such as BOD, DO, and turbidity in the absence of nutrient supplementation.

The use of urea and NPK 15:15:15 fertilisers enhanced the bioremediation capability of the indigenous microbes present in the wastewater. This was evident in the significant reductions in BOD and turbidity as well as increase in the DO of the wastewater in the course of bioremediation.

Combining the two fertilisers is more effective in remediating domestic wastewater as evident in the superior results obtained when both urea and NPK were used together.

Urea and NPK fertilisers are effective in reducing organic matter (decrease in BOD and increase in DO) to acceptable limits as specified by FEPA.

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