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INVESTIGATION OF ANAEROBIC PROCESSES IN SEPTIC TANK AS A WASTEWATER TREATMENT OPTION

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ABSTRACT

The demand for quality drinking water is a necessity across the world today considering the high level of increase in population and global warming. It is therefore necessary to adopt different alternative measures in converting wastewater into drinkable water. This project therefore aimed at investigating the anaerobic processes in septic tank as a wastewater treatment option using wastewater from a septic tank-: a case study of Etsako West Local Government Area of Edo State. Personal observation and laboratory analysis were used for data collection. Water samples were taken from a septic tank to assess the level of temperature, conductivity, pH, odour, COD, BOD, and OD in the water. The result showed the presence of BOD in the water sample was higher (106.6883 mg/L) than the WHO tolerance limit of 5 mg/L for drinking water. The sample was heavily loaded with colloidal matter (turbidity: 42.09 NTU), organic matter (COD: 106 mg/L), and suspended matter (turbidity: 42.09 NTU). This shows that the discharge of septic tank effluent to water bodies without treatment poses a serious health risk to humans and the environment. Therefore, the following recommendations were made: provision of adequate waste disposal facilities to cater for both solid and liquid waste, enforcement of existing health and hygienic regulations guiding abattoir operation.

Keywords: Anaerobic, Groundwater, Pathogens, Sewage, Treatment, Wastewater

INTRODUCTION

The treatment of wastewater through septic tank systems remains a critical yet often underappreciated component of public health and environmental sustainability, particularly in regions where centralized sewerage infrastructure is absent or impractical. This study investigates the anaerobic processes occurring within septic tanks as a wastewater treatment option and evaluates their reliability in effectively managing domestic sewage (Agbogo *et al*., 2024). The problem at the core of this research stems from the inadequate performance of septic tanks, especially in developing countries, where untreated or poorly treated wastewater infiltrates groundwater, posing significant risks to public health and the environment. Researchers have demonstrated that many septic tanks fail to achieve even average performance over their operational lifetime, functioning merely as conduits for raw or undertreated sewage to contaminate soil and groundwater. Given that groundwater serves as a primary source of potable water in many communities—often consumed without treatment under the erroneous assumption of its inherent cleanliness—this contamination perpetuates the prevalence of waterborne diseases such as typhoid fever, diarrhea, giardiasis, and hepatitis, among others. Previous studies have highlighted the consequences of septic tank inefficiencies. For instance, Weissman *et al*. (1976), Bridgman *et al*. (1995), and Taylor *et al*. (1981) documented disease outbreaks linked to groundwater contamination from failing onsite disposal systems, with Collick *et al*. (2006) estimating that nearly 40% of such outbreaks in groundwater-dependent regions can be traced to these failures. In developing nations like Nigeria, where over 46% of the population relies on septic tanks, the lack of systematic design, construction, and maintenance exacerbates the problem. Bounds (1997) described the septic tank as an anaerobic reactor designed to collect wastewater, separate solids, digest organic matter, and discharge treated effluent, yet its effectiveness hinges on proper management. The absence of a deterministic approach to maintenance, particularly regarding sludge dislodging intervals, often results in either excessive operational cost from frequent dislodging or reduced efficiency due to sludge accumulation. Furthermore, effluent from malfunctioning systems can contribute to environmental degradation, such as algae blooms in waterways, a problem that nitrogen-reducing technologies or proper leach field siting could mitigate. The aim of this study is to determine the anaerobic processes within septic tanks and assess their reliability as a wastewater treatment solution, through the determination of key parameters such as temperature, pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and chemical constituents. Building on prior work, this research seeks to advance knowledge by developing a systematic and rational approach to septic tank design and maintenance.

MATERIALS AND METHODS

Data Collection

Wastewater samples were collected from a septic tank located at No. 39, Behind Sawmill, Sabo, Auchi, Edo State, Nigeria. A total of three samples were obtained using a grab sampling technique, where each sample was collected at a single point in time from the septic tank's effluent outlet to ensure representativeness of the wastewater characteristics. Samples were obtained using clean 100 cm³ polyethylene containers, handled with nitrile gloves to prevent contamination, and labeled with the collector's name, date, and sampling location. All samples were transported to the Water

Laboratory at Auchi Polytechnic, Auchi, for subsequent analysis.

Data Analysis and Experimental Procedures

Experiments were conducted to evaluate anaerobic processes in the septic tank wastewater through physical and chemical analyses. Physical parameters assessed included temperature, pH, odor, and conductivity, while chemical analyses encompassed dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), hardness, iron, magnesium, nitrogen, and phosphorus. All experiments were performed in the Water Laboratory at Auchi Polytechnic unless otherwise specified.

Physical Analysis

Physical analyses were conducted to determine the impurity levels of the wastewater based on key physical properties.

Determination of Temperature

A 100 cm³ sample of septic tank wastewater was poured into a 250 cm³ beaker. A thermometer was carefully inserted into the wastewater sample, ensuring it was submerged without touching the beaker's walls or base. The temperature reading was allowed to stabilize, typically after 1-2 minutes, and then recorded. This process was repeated three times with fresh 100 cm³ samples to ensure accuracy. The average temperature was calculated by summing the three recorded values and dividing by three.

Determination of pH

The Hanna pH meter was first calibrated using 50 cm³ of hydrochloric acid (HCl) to ensure accurate readings, followed by rinsing the probe with distilled water and wiping it clean with tissue paper to remove any residual contaminants. A 100 cm³ sample of septic tank wastewater was measured into a 250 cm³ beaker. The pH meter probe was then inserted into the sample, ensuring it was fully submerged. The reading was recorded once the digital display stabilized, indicating a consistent pH value.

Determination of Odor

A 100 cm³ sample of septic tank wastewater was measured using a 100 cm³ measuring cylinder and transferred into a pot. The pot was placed on a stove and heated for several minutes. During heating, the sample was observed for the emission of an unpleasant smell, which was noted as confirmation of odor presence. Tasting was avoided due to the strong, unpleasant odor detected.

Determination of Conductivity

To determine the conductivity of the wastewater, the conductivity meter probe was first calibrated using 50 cm³ of hydrochloric acid (HCl). The probe was then rinsed with distilled water and wiped clean to ensure accuracy. Next, a 100 cm³ sample of wastewater was measured into a 250 cm³ beaker. The calibrated probe was inserted into the sample, and the conductivity reading, in microsiemens per centimeter (µS/cm), was recorded once the digital display on the 4510 Conductivity Meter stabilized.

Chemical Analysis

Chemical analyses were performed to quantify organic and inorganic constituents in the wastewater, including DO, COD, BOD, hardness, iron, magnesium, nitrogen, and phosphorus.

Determination of Dissolved Oxygen (DO) – Winkler's Method

To determine the dissolved oxygen (DO) in the wastewater using Winkler's method, a 300 cm³ BOD bottle was filled with the wastewater sample. Using a pipette, 2 cm³ of manganese sulphate and 2 cm³ of alkali iodide were added, and the bottle was inverted to mix thoroughly. Next, 2 cm³ of concentrated sulphuric acid was carefully added above the liquid surface, and the bottle was inverted several times to ensure proper mixing. The sample was then stored in a cool, dark place for 5 hours. After storage, a 20 cm³ aliquot of the sample was transferred to a conical flask and titrated with sodium thiosulphate until the solution became clear. Then, 2 cm³ of starch indicator was added, turning the solution blue and titration continued until the solution cleared again. The DO concentration (mg/l) was calculated based on the volume of sodium thiosulphate used during titration.

Determination of Chemical Oxygen Demand (COD) – Titrimetric Method

To determine the Chemical Oxygen Demand (COD) of the wastewater using the titrimetric method, a 20 cm³ wastewater sample was measured into a round-bottom flask containing glass beads to prevent bumping. Then, 1 cm³ of potassium dichromate solution and 2.5 cm³ of sulfuric acid were added to the flask, and the mixture was digested. After cooling to room temperature, 2 drops of ferroin indicator were added to the solution. The solution was then titrated with ferrous ammonium sulphate until a reddish-brown color appeared, indicating the endpoint. The COD was calculated based on the volume of ferrous ammonium sulphate used in the titration.

Determination of Biochemical Oxygen Demand (BOD) – 5-Day Test

To determine the Biochemical Oxygen Demand (BOD) of the wastewater using the 5-day test, two 300 cm³ BOD bottles were filled with wastewater and labeled as Sample 1 and Sample 2. The dissolved oxygen (DO) of Sample 1 was measured immediately using Winkler's method. Sample 2 was incubated at 20°C for 5 days, after which its DO was measured using the same method. The BOD (mg/l) was calculated as the difference between the initial DO (Sample 1) and the final DO (Sample 2), divided by the sample volume.

Determination of Hardness

To determine the total hardness of the wastewater, a 50 cm³ wastewater sample (diluted if high in calcium) was placed in a conical flask. Then, 1 cm³ of ammonia buffer and 5–6 drops of Eriochrome Black-T indicator were added, turning the solution wine red. A burette filled with EDTA solution was used to titrate the sample until the color changed to blue, and the volume of EDTA used was recorded. The process was repeated to ensure concordance. For temporary hardness, another 50 cm³ wastewater sample was boiled, cooled, and titrated following the same procedure with EDTA, ammonia buffer, and Eriochrome Black-T until the color changed from wine red to blue, with the volume of EDTA recorded. Total hardness was calculated based on the EDTA volume used for the unboiled sample, while temporary hardness was determined from the boiled sample.

Determination of Iron
To determine the iron concentration in the wastewater using UV-Visible spectrophotometry, a 10 cm³ sample was first tested for pH and adjusted to 7 using 6.0 M NaOH or HCl if necessary. A 25 cm³ aliquot of the sample was filtered through a 0.45 µm HPLC filter if solids were present, then treated with 0.1 cm³ of concentrated nitric acid. From this, 5 cm³was pipetted into a test tube containing ammonium thioglycolate buffer from the Iron Cell Test Kit. After mixing and waiting 3 minutes, a purple color indicated the presence of iron. The absorbance of the solution was measured at 565 nm using a Perkin Elmer Lambda 35 UV-Visible spectrometer with polystyrene cuvettes. The iron concentration was calculated using a calibration curve. The procedure was repeated to ensure reproducibility.

Determination of Nitrogen (Nitrate)
To determine the presence of nitrate in the wastewater using the diphenylamine method, 10–15 drops of the wastewater sample were placed in a glass container. A few drops of the prepared reagent solution (0.5 g diphenylamine dissolved in 20 cm³ distilled water, with concentrated sulfuric acid added to a total volume of 100 cm³) were added to the sample. The mixture was observed for up to 30 minutes, and the development of a deep blue color indicated high nitrate levels.

Determination of Magnesium
To determine the magnesium concentration in the wastewater using atomic absorption spectroscopy (AAS), wastewater samples were first centrifuged and filtered onsite through 0.45 µm membrane filter paper to remove particulates. The filtered samples were then analyzed for magnesium (along with calcium) using a Varian SpectrAA220 flame atomic absorption spectrometer. The magnesium concentration was quantified based on the absorbance measured by the instrument, while phosphorus was separately analyzed using colorimetric flow injection analysis on a LaChat QuickChem 8000.

Determination of Phosphorus
To determine the phosphorus (phosphate) concentration in the wastewater colorimetrically, three test tubes were filled to the mark with the wastewater sample. One test tube was treated by adding 1.0 cm³ of phosphate acid reagent (ammonium heptamolybdate) and mixed thoroughly. Then, 0.1 g of phosphate reducing reagent was added to the same tube and dissolved. After 5 minutes, the treated tube was placed in an axial reader, flanked by two untreated tubes (blanks) for comparison. The color of the treated sample was compared to standard color references using an octet comparator under natural light to quantify the phosphate concentration.

RESULTS AND DISCUSSION
The physical and chemical parameters of wastewater samples from a septic tank were evaluated during two experimental stages: field analysis (Stage 1) and laboratory analysis (Stage 2). The results are summarized in Table 1 below.

Table 1: Physical and Chemical Parameters of Septic Tank Wastewater

S/N	Parameters	Units	Septic tank
1	Physical analysis		
	Temperature	℃	26.5
	pH	-	6.7
	Odour	-	-
	Conductivity	µs/cm³	108
2	Chemical analysis		
	DO	mg /l	0.6883
	COD	mg /l	106
	BOD	mg /l	106.6883
	Hardness	mg /l	184
	Iron	mg /l	0.08139
	Nitrogen	mg /l	0.0876
	Magnesium/Calcium	mg /l	67.6284
	Phosphorus	mg /l	0.03

Physical Characteristics
During Stage 1 (field analysis), the septic tank wastewater exhibited a temperature of 26.5°C, a near-neutral pH of 6.7, and a conductivity of 108 µS/cm, indicative of moderate ionic content. In Stage 2 (laboratory analysis), turbidity was measured at 42.09 NTU, suggesting a relatively low concentration of suspended solids compared to untreated wastewater. These physical properties align with findings from Tchobanoglous *et al*. (2003), who reported typical septic tank effluent temperatures ranging from 20–30°C and pH values of 6.5–7.5, reflecting stable anaerobic conditions.

Chemical Characteristics
The chemical analysis revealed low dissolved oxygen (DO) concentration of 0.6883 mg/l, consistent with the anaerobic environment of the septic tank. The chemical oxygen demand (COD) and biochemical oxygen demand (BOD) were 106 mg/l and 106.6883mg/l, respectively, indicating a high organic load. The close alignment of COD and BOD values suggests that the organic matter is predominantly biodegradable, a characteristic also noted by Gray (2010) in septic tank effluents, where COD/BOD ratios typically range from 1.0 to 1.5. Compared to aerobic treatment systems, such as those studied by Abualhail *et al*. (2016), which reported effluent BOD values of 20–50mg/l, the higher BOD in this study reflects the anaerobic nature of septic tank treatment, which is less effective at reducing organic matter. Hardness (184mg/l), iron (0.08139mg/l), nitrogen (0.0876mg/l), and phosphorus (0.03mg/l) were present in low concentrations, indicating effective removal of these constituents during treatment.

Treatment Efficiency
The wastewater samples exhibited near-neutral pH (6.7) at volumes of 100 cm³ and 150cm³, suggesting successful neutralization of acidity during anaerobic digestion. This is comparable to findings by Lettinga *et al*. (1999), who observed that anaerobic systems maintain pH stability through buffering by bicarbonate produced during digestion. The reduction in turbidity (42.09 NTU) and trace elements

(e.g., iron, magnesium/calcium) highlights the septic tank's efficiency in solids settling and anaerobic degradation. However, the effluent COD (106 mg/l) and BOD (106.6883 mg/l) exceed typical regulatory discharge limits (e.g., 50mg/l BOD in the U.S. Clean Water Act), contrasting with aerobic systems like moving bed biofilm reactors (MBBR), which achieve COD reductions to below 50 mg/l (Ødegaard *et al*., 2010). This indicates that while the septic tank reduces pollutants, additional treatment may be required for environmental discharge.

CONCLUSION

The anaerobic processes within the septic tank demonstrated considerable efficiency in reducing physical and chemical parameters of wastewater. The high COD (106mg/l) and BOD (106.6883 mg/l) levels, coupled with low DO (0.6883mg/l), confirm robust organic matter degradation under anaerobic conditions, consistent with Tchobanoglous *et al*. (2003), who noted that septic tanks typically achieve 25–50% BOD removal. Compared to aerobic systems, such as those reported by Abualhail *et al.* (2016), which achieved over 80% BOD reduction, the septic tank's performance is less pronounced, reflecting its reliance on anaerobic microbial activity. The low concentrations of iron (0.08139mg/l), nitrogen (0.0876 mg/l), and phosphorus (0.03mg/l) align with findings from Gray (2010), indicating minimal environmental risk from these constituents. However, the effluent's organic load remains higher than that of advanced treatments like MBBR (Ødegaard *et al*., 2010), suggesting that while the septic tank is effective for preliminary treatment, it is not sufficient for meeting stringent discharge standards without further processing. These results underscore the septic tank's role as a viable anaerobic treatment option for non-potable reuse or controlled discharge, provided additional polishing steps are considered where necessary.

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