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Evaluation of Some Microbiological and Physico-chemical Composition of Domestic Wastewater in Rivers and Bayelsa States

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: This research study aims at ascertaining the inhibitive contributions of these domestic effluents even as they flow from drains into the rivers.
Study Design: The microbiological and physico-chemical composition of domestic wastewater in Rivers and Bayelsa States was achieved experimentally.
Place and Duration of Study: The study was carried out in Rivers and Bayelsa states, Nigeria, between August 20016 and January 2017.
Methodology: The waste water samples were aseptically collected from domestic points using 1 litre sterile polyethylene bottles filled with ice and was immediately taken to the laboratory for analysis to improve reliability of data and they were stored at 4℃ for further analysis.
Results: The physicochemical analysis of wastewater collected from 20 stations were investigated. These parameters were analyzed by standard methods. The color of the collected sewage water was pale yellow to black and was turbid in some selected stations. Unpleasant odor was observed

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in all selected stations. The pH of the wastewater varied from 6.0 to 7.3, while the water conductivity ranges from 650 to 2390 μScm^{-1}. The maximum total suspended solid was 182 mg/l, and the maximum biological oxygen demand was 569.5 mg/l. The chemical oxygen demand of the selected stations varied widely (507.1 – 602.9 mg/l), and the dissolved oxygen content varied from 0.01 to 0.242 mg/l. The nitrate content was found to be maximum in station G (18.5 ppm), and the samples show high content of bacteria in all the stations.

Conclusion: This study anchors on the need for effective sewage treatment of domestic, industrial and municipal effluent before they are discharged into the environment. This will help to meet up with the long-term challenges of environmental pollution, improve standard of living and health, and also enhance economic opportunities and good sustainable development.

Keywords: Physico-chemichemical; effluents; domestic; waste-water; discharged.

1. INTRODUCTION

Wastewater is a term used to describe a complex mixture of wastes comprising all water discharged directly from domestic homes, industrial and agricultural business, road run-off, and any materials that may leak through damaged sewerage systems [1].

Domestic wastewater is a complex and dynamic composition of mixture of natural and man-made organic and inorganic materials, and changes in response to factors such as the weather and the diet of the local community [2,3]. For this reason, the monitoring of wastewater can be a complicated and in exhaustive process [4].

Untreated sewage pool typically contains a mixture largely comprising of hazardous contaminated water (99.9 %), with faeces, food, grease, oils, plastics, salts, detergents, grit, pesticides, ammonia, heavy metals and bacterial cells [5,6].

Pollution from wastewater is currently the greatest threat to the sustainable use of surface and groundwater in Nigeria today. Domestic, hospital and industrial effluents and raw untreated sewage are often discharged into the open and fresh-water sources such as the majority of villages and rural areas discharge their raw domestic wastewater directly into the waterways.

Rain or flood can carry an immense dose of pollutants such as domestic, hospital and industrial wastes can be washed into waterways in Nigeria. In the investigations of [7-9], the authors stated that even with gentle rains, urban and rural runoff is the biggest source of water pollution remaining today. The wastewater eventually percolates or is washed into the water bodies by rainstorms. The stagnating pools of wastewater in the open gutters and on the roads often provide the breeding grounds for mosquitoes and habitat for several bacteria and viruses.

This may be the primary reason many sections of rivers in Nigeria remain polluted and fail to meet national and World Health quality standards.

Waterborne pathogens could be spread within the freshwater after a contamination by animal or human waste due to heavy rainfall discharge in combined sewer systems (CSS). When the flow exceeds the CSS capacity, the sewers overflow directly into surface water body [10].

Apart from the already well known problems of pathogens and viruses, some emerging sources of concern were highlighted which include endocrine disrupters such as oestrogens, steroids, dioxins, phthalates and alkyl phenol exylates, which would all pose a threat to the food chain if they got into rivers or the sea [11-13].

Even though the risk of diseases outbreaks linked to mains of drinking water, it is low in developed countries, and even properly constructed onsite wastewater treatment systems may cause a waterborne outbreak [14,15].

The prevalence of pathogenic microbes in treated wastewater has raised concerns about the capacities of existing treatment to remove theses microbes [16].

In Nigeria almost 80 % of the river has become polluted due to the discharge of domestic sewage and industrial effluents into the water bodies such as rivers, streams and lakes without proper treatment [13].

The sewage water discharged from various domestic, house-boats and industrial sources has been characterized by various researchers [17-20]. Environmental management is one of the important issues as the urbanization trend continues globally. The under-management of municipal/domestic wastewater in many cities in Nigeria is a major challenge. Management of wastewater in metropolitan city homes is a very difficult task. The hazardous disposal of wastewater results in water and terrestrial pollution. These wastewater contaminates the water bodies, causing the mortality of aquatic biological resources. Hence, the role of wastewater treatment plants will be in sustainable use as they make the water usable for various purposes [21]. The major objective of the present study was to characterize the wastewater discharged from different domestic sewages in Rivers and Bayelsa States, Nigeria. A study like this will improve our understanding on the quality of wastewater being discarded into the environment due to various anthropogenic activities.

2. MATERIALS AND METHODS

The study was carried out in Rivers and Bayelsa states, Nigeria. Rivers and Bayelsa States are located in the Niger Delta region. It lies within latitudes 4°20' and 5^{0} 50'N and longitudes 6°20' and 7^{0} 35'East. It is bounded on the south by the Atlantic Ocean, to the north by Imo and Abia states, to the east by Akwa Ibom State and to the West by Bayelsa State, while Bayelsa state lies within latitude 4°15' and 5^{0} 23' N, and longitude 5°15' and 6^{0} 45' E. The state is bounded to the north by Delta State, to the east by Rivers State, and to the south and west by the Atlantic Ocean.

2.1 Materials

Thermometer, Jenway 4020 conductivity meter (Bibby Scientific, Stone), Oven dryer, Turbidity meter, Whatman GF/C glass microfiber, Bran and Luebbe Continuous Flow Auto-analyser 3 (SPX, Northampton), Palintest Persulfate Digestion tube test kit (Total Phosphorus/12) (Palintest, Tyne & Wear), Hach test kit and a Hach DR/3000 spectrophotometer (Hach, Loveland), Colorimeter, Allylthiourea, Hydrazine sulphate, Cupric iron catalyst, Acidic sulphanilamide, Ammonium molybdate, Ascorbic acid, Acetic acid, Sodium hydroxide, Mercuric sulphate, Potassium dichromate, and Sulphuric acid.

2.2 Methods

In this research, some microbiological and physicochemical parameters such as color, odor, pH, electrical conductivity (EC), total suspended solids (TSS), biological oxygen demand (BOD), carbon oxygen demand (COD), dissolved oxygen (DO), and nitrates of the wastewater were tested.

The waste water samples were aseptically collected from domestic points using 1litre sterile polyethylene bottles filled with ice and was immediately taken to the laboratory for analysis to improve reliability of data and they were stored at 4℃ for further analysis.

The microbiological and physicochemical parameters observed in this study may serve as an indicator of the fertility or pollution level of the study areas. The experimental data on physicochemical properties of water samples collected from different domestic points of in the study areas are shown in Figs. 1–7.

2.3 Dissolved Oxygen

Dissolved oxygen determined electrometrically using a YSI 5730 multi- parameter data logger (YSI, Yellow Springs, WA), fitted with a field probe, which was also used to record temperature. Temperature was taken using at the same time using the same meter as the one used for DO, following the same procedure.

The areas of case study are Rivers and Bayelsa States, Nigeria. Effluent samples were collected from twenty (20) different areas in Port Harcourt City and Yenagoa local government areas of Rivers and Bayelsa States.

2.4 Total Suspended Solids (TSS)

Assessment of TSS was performed in accordance with the APHA (2008) method. A measured sample was filtered through a Whatman GF/C glass microfibre filter, 9 cm diameter, which had previously been weighed to four decimal places. After oven drying for two hours at 105℃ the filters were then reweighed and the TSS was calculated relative to the original sample size using the following equation:

$$TSS = \frac{(B-A)\times 1000[mg/L]}{V}$$

Where:

A = Initial paper weight (mg)

B = Paper weight plus sample dried at 105℃ (mg)
V = volume filtered (mL) (APHA, 2008)

2.5 Biochemical Oxygen Demand (BOD)

BOD was determined using the APHA (1998) method (Clesceri & Greenberg, 1998). The BOD_5 is a measure of oxygen required to degrade a sample of waste over five days by the activity of microorganisms as they oxidize the organic matter. Standard conditions were applied to the BOD test, which are incubated at 20℃ in the dark, under aerobic conditions.

Samples were collected as described above and diluted appropriately to prevent total oxygen depletion during incubation. The appropriate amount of dilution water to be prepared was determined by visual assessment of the turbidity of the sample. A more turbid sample required greater dilution. Dilution water was made with enough time to let it reach room temperature. A small air-stone was added to saturate the water, and 1mL per litre of each of the following solutions were added to the water:

$FeCl_3.6H_2O\ (0.125g/L)$
$CaCl_3.2H_2O\ (36.42g/L)$
$MgSO_4.7H_2O\ (25g/L)$

Phosphate buffer, pH 7, containing per litre:
$KH_2PO_4\ (52.5\ g),\ NaOH\ (8.8\ g),\ and\ (NH_4)2SO_4\ (2.0\ g)$

Allylthiourea (1 g/L).

Allylthiourea was added as an inhibitor of nitrification, in order to determine carbonaceous oxidation only. The samples were incubated in the dark at 20℃, along with a blank sample, which was the dilution water. Prior to, and immediately after incubation, the DO of each sample was recorded, and the following formula used to calculate the BOD, in accordance with the APHA method (1998):

$$BOD = F[(D_1-D_2)-(F-1/F)(B_1-B_2)]$$

Where:

D_1 = DO concentration of sample before incubation
D_2 = DO concentration of sample after incubation
B_1 = DO concentration of blank before incubation
B_2 = DO concentration of blank after incubation
F = dilution factor (volume of diluted sample/volume of sample aliquot) (APHA, 1998).

2.6 Chemical Oxygen Demand (COD)

COD was assessed according to the APHA (2008) method using a Hach test kit and a Hach DR/3000 spectrophotometer (Hach, Loveland). COD is a measure of the oxygen equivalent of a sample containing organic material which is susceptible to oxidation by a strong chemical oxidant. Samples were diluted according to visual assessment and filtered samples to measure soluble COD were used neat. The test kit was used according the manufacturer instructions and final values for COD were determined according to the dilution factor used to prepare the original samples.

Sample (2 mL) was added to a test kit tube, which contained a mixture of mercuric sulphate, potassium dichromate, and sulphuric acid. A blank tube, which contained 2 mL of distilled water instead of a sample, was also prepared in this way. The tubes were boiled at 150℃ for two hours. After boiling, the tubes were allowed to cool and the blank tube was used to zero the colorimeter (HACH DR 700) which operated at a fixed wavelength of 610 nm. Readings were taken for each tube and final values were determined according to the dilution factor used.

All analyses were performed and the results were expressed by the mean of the two samples plus the standard error.

2.7 Total Oxidised Nitrogen (TON) (mg/L)

2.7.1 Nitrite ($NO2^-$) (mg/L)

Total oxidised nitrogen (TON) is used to assess the concentrations of nitrite (NO_2^-) and nitrate (NO_3^-) in a sample together. By measuring the concentration of nitrite separately, therefore, it is possible to determine the concentraction of nitrate. TON and nitrite were measured using filtered samples, with the Bran and Luebbe Continuous Flow Auto-analyser 3 (SPX, Northampton) according to the manufacturer's instructions. The autoanalyser brings the sample to an alkaline pH and adds hydrazine sulphate and a cupric iron catalyst. A colour change is effected after the addition of acidic sulphanilamide, which is measured at 520 nm.

2.8 Plate Dilution Frequency Assay

The most probable number (MPN) plate count technique is based on the presence or absence of colony forming units in standardized media conditions. It is performed using media selective for groups of bacteria of interest, and is widely used to monitor bacterial populations over a period of time.

Plates were dried overnight on the bench before use, and the bottom of each petri-dish was divided into sixteen segments with a marker pen. Purity plates were incubated with the inoculated plates to check for contamination. One plate in each group was inoculated with sterile water as a negative control. One plate in each group was inoculated with an overnight culture of *E.coli* as a positive control.

A serial dilution was performed with 1 mL of a sample which was mixed by inverting 5 times. Working from the highest dilutions, eight 10 µl aliquots were spotted onto one half of a plate of each dilution. After incubation, positive growth for each dilution was recorded. Three replicates of each MPN were performed per sample.

3. RESULTS AND DISCUSSIONS

The results of the microbiological and the physicochemical parameters observed in this study may serve as an indicator of the fertility or pollution level of the study areas. The experimental data on microbiological and physicochemical properties of water samples collected from different domestic areas. Table 1 presents results from domestic waste water collected from twenty points.

3.1 Color and Odor of Wastewater

The color and odor of the wastewater typically depends differently on the domestic activities and municipal areas. The measurement and removal of color are essential part as it is unfit for recycling without proper treatment. The wastewater collected during the study was colorless in stations B, C, F, I, K, N, P, and T, respectively. Moreover, the wastewater was pale yellow in color in stations A, D, J, L, O, and S. Blackish color was observed in stations E, M, and Q. However, the water was so turbid in stations G, H, and R. The turbidity is caused by a wide variety of suspended materials that range in size from colloidal to coarse dispersion. In this study, unpleasant odor was noted in all stations.

3.2 pH

pH readings were taken from all 20 collected water samples using a Jenway 3305 pH meter (Bibby Scientific, Stone) immediately after collection. The meter was calibrated before each sampling suite was performed, with commercially prepared standards of pH 4 and 7 (Fisher Scientific, Loughborough), and the result was shown in Fig. 1. The pH of the water is known to influence the availability of micronutrients/nitrifying bacteria as well as trace metals. It is well known that the pH is an important parameter in evaluating the acid–base balance of water. A pH value of 7 is neutral; a pH less than 7 is acidic, and and a pH greater than 7 represents base saturation or alkaline. The principal component regulating ion pH in natural waters is the carbonate, which comprises CO_2, H_2CO_3, and H_2CO_3.

3.3 Dissolved Oxygen (DO)

The DO content of the wastewater collected from different sources of domestic areas was shown in Fig. 2. BOD directly influences the amount of DO in waste water. The greater the BOD, the more rapidly oxygen is depleted in the water. This means that less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low DO: aquatic organisms become stressed, suffocate, and die. The DO is a measure of the degree of pollution by organic matter, the destruction of organic substances, and the self-purification capacity of the water body.

The DO results from the domestic facilities ranged from (0.18-0.25) mg/l with all of the points having a value lower than specified (4.0- 5.0) mg/l. The DO results were all below the minimum value expected for effluent discharge. This is a great concern and will pose danger for aquatic organisms.

3.4 Electroconductivity

Water conductivity is mainly attributed to the dissolved ions liberated from the decomposed plant matter and input of inorganic and organic wastes. EC values are noted to be different for various samples, ranging from 650 to 2,390 μScm^{-1}, and the result was shown in Fig. 2. EC depends on the dissolved solids in the discharged water. The EC being the measure of dissolved solid in solution (the levels of ions in a system) implies that station E had more dissolved solids than other sites. High EC values indicate the presence of high amount of dissolved inorganic substances in ionized form. The fluctuations in EC in any particular location depends on the fluctuation in TDSs and salinity.

3.5 Total Suspended Solids (TSS)

Assessment of TSS was performed in accordance with the APHA (2008) method.

The total suspended solids (TSS) in the sample points ranged from (66-185) mg/l as shown in Fig. 4. All the points tested indicated higher values than specified limit (45 mg/l) by regulatory agents. There might be utmost need to undertake centrifugation exercise in order to separate the suspended solids before discharge into the water body. Prudent measures should be undertaken to separate the suspended solids before discharge.

Table 1. Type and Location of sampling site

S/N	Sample types	Location	Stations
1	Domestic	Rivers	(A,B,D,G,J,K,C,E,F,G,J)
2	Domestic	Bayelsa	(H,N,P,R,T,I,L,O,S,M,Q)

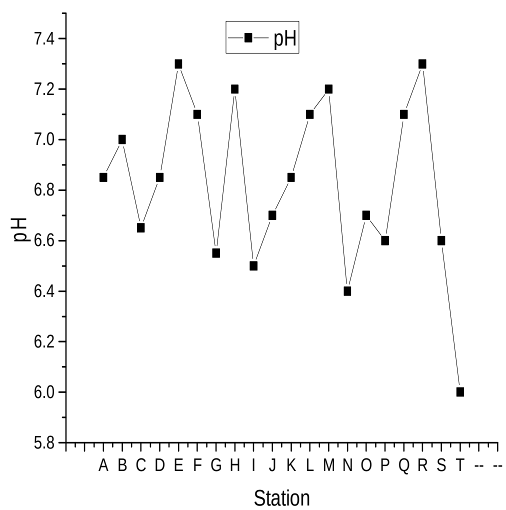

Fig. 1. Variation of pH at selected stations

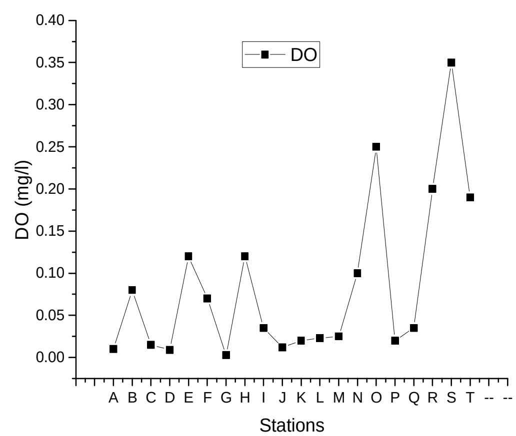

Fig. 2. Dissolved oxygen content in sewage water

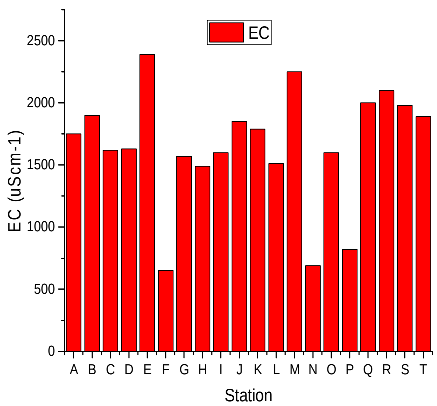

Fig. 3. Variation of electrical conductivity in sewage water

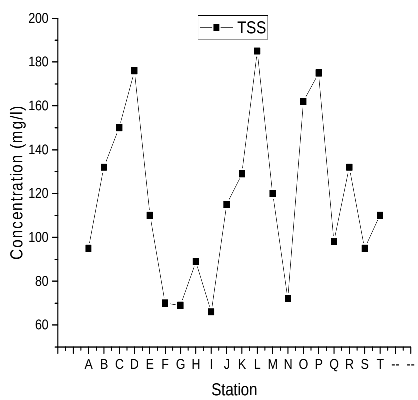

Fig. 4. Total suspended solids in sewage water

3.6 Biochemical Oxygen Demand (BOD)

BOD showed the minimum value of 246.3 mg/l and the maximum value of 569.5 mg/l. The registered BOD value was high in the present study (Fig. 5). BOD increases due to biodegradation of organic materials that exerts oxygen tension in a water body. Increases in BOD can be due to heavy discharge of industrial wastewater effluent, animal and crop wastes, and domestic sewage. BOD value has been widely adopted as a measure of pollution in the particular environment. It is one of the most common measures of organic pollutant in water. It indicates the amount of organic matter present in water. Sources of BOD in aquatic environment include leaves and dead plants, woody debris, animals, animal manure, industrial effluents, wastewater treatment plants, feedlots, and food-processing plants and urban storm water runoff.

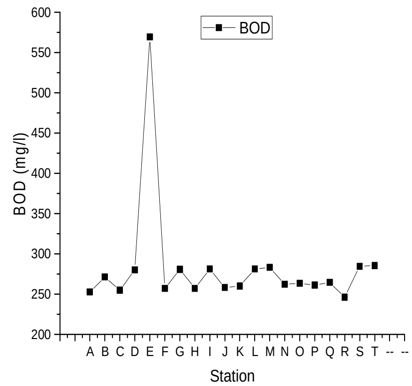

Fig. 5. Biological oxygen demand of wastewater from selected stations

3.7 Chemical Oxygen Demand (COD)

COD showed the minimum value of 506.9 mg/l and the maximum value of 602.9 mg/l (Fig. 6). All organic compounds with few exceptions can be oxidized by the action of strong oxidizing agents under acidic condition. The COD determination is a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant. While determining COD, oxygen demand value is useful in specifying toxic condition and presence of biologically resistant substances. The COD and BOD values are a measure of the relative oxygen-depletion effect of a waste contaminant. Both have been widely adopted as a measure of pollution effect. COD is also one of the most common measures of pollutant organic material in water. COD is similar in function to BOD, in which both measure the amount of organic compounds in water.

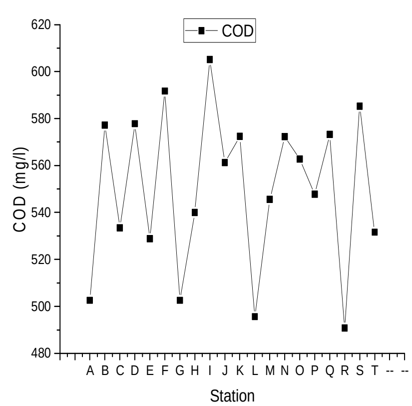

Fig. 6. Chemical oxygen demand of municipal wastewater

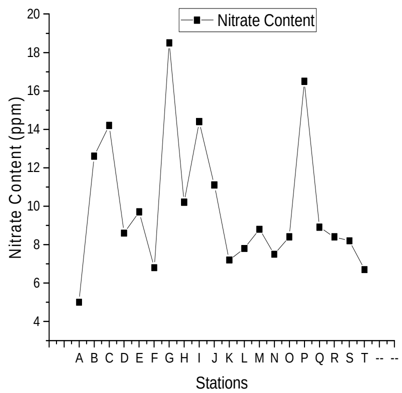

Fig. 7. Nitrate content of sewage water

3.8 Total Oxidized Nitrogen (TON) (mg/L)

The nitrate content of wastewater samples varies from 5 to 18.5 ppm, and the result was shown in Fig. 7. Nitrate content is an important parameter to estimate organic pollution in a particular environment, and it represents the highest oxidized form of nitrogen. Nitrate is one of the very common contaminants in ground water and surface water. Nitrate occurs naturally in source water as a result of decaying plants. However, there are other manmade sources of nitrate that can increase its presence in source waters to dangerous levels. Agricultural sources of nitrates include livestock waste matter and chemical fertilizers. The presence of nitrates in the water samples is suggestive of some bacterial action and bacterial growth.

3.9 Plate Dilution Frequency Assay

The media used during this study are detailed in above Table 2. *Nitrobacter* medium (a.) was used for the presumptive growth of ammonia oxidizing bacteria. *Nitrosomonas (b.)* medium was used for the presumptive growth of nitrite oxidizing bacteria, and casein peptone starch nitrate (CPSN) medium (c.) was used for denitrifying bacteria. The appropriate medium was selected, made and poured into petri dishes or test tubes.

In Nigeria, since there are no sewerage, one would have to start by trucking or hauling the sewage to the treatment facility. A reservoir could be built to hold enough volume to constantly supply the treatment plant on a batch treatment methodology. The wastewater treatment plant should be designed to purify city waste water so that it can be returned to the river to be reused. For new towns, Government should plan to install a wastewater treatment system from the beginning. Home builders should be required to connect all homes built to a sewer line that is connected back to the sewage treatment plant.

Table 2. Composition of media used in the study

a. Nitrobacter Agar:

$NaNO_2$	0.2g
$NaCO_3$	0.5g
NaCl	0.25g
K_2HPO_4	0.25g
$MgSO_4{\cdot}_7H2O$	0.15g
$FeSO_4$	0.2g
Technical Agar (Oxford, Cambridge, UK)	6.5g
DH_2O	to 500 mL

b. Nitrosomonas Agar:

$(NH_4)_2SO_4$	10g
$K2HPO_4$	3.75g
KH_2PO_4	1.25g
$FeSO_4.7H_2O$	0.05g
$MgSO_4.2H_2O$	0.15g
$CaCl_2.2H_2O$	0.01g
Technical Agar (Oxford, Cambridge, UK)	6.5g
dH_2O	to 500 mL

c. Casein Peptone Starch Nitrate (CPSN):

Starch	0.3g
Casein hydrolysate	0.3g
Bactopeptone (Oxford, Cambridge, UK)	0.3g
Glycerol	0.6 mL
KH_2PO_4	0.6 g
$MgSO_4.7H_2O$	0.06 g
KNO_3	0.11 g
0.1% alcohol bromothymol blue	6 mL
dH_2O	to 500 mL

Homes in the western world are expensive partly because all homes are required to be connected to a sewer line. These lines are buried deep underground such that it is difficult to accidentally break them when constructing other structure. One method of disposal that can be very beneficial in a place like Nigeria would be land application as soil conditioner and/or fertilizer depending on the nitrogen content of the sludge. The treated sludge could generate a revenue stream from sale to resident farmers as soil conditioner or fertilizer.

4. CONCLUSION

This study concluded that the waste water quality in Rivers and Bayelsa States needs a serious effort in limiting and manage the numbers of chemical and microbial organisms released into the system, this will help to meet up with the long-term challenges of sound environmental management, improve standard of living and health, enhance economic opportunities and make for sustainable development. According to WHO and USEPA recent news and reports, most tap, boreholes, streams and rivers water in use are not safe for drinking due to heavy industrial and environmental pollution. Toxic chemical, heavy metal and bacteria in waste water when disposed to rivers or are leached underground make people sick while exposing them to long term health condition. Water quality should be controlled in order to minimize acute problem of water related disease which are endemic to health of man. Therefore, to make this a win-win venture, a sustainable and effective thorough sanitary condition and legislation should be given to the water bodies in order to maintain a good water quality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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