academicJournals

Vol. 8(10), pp. 414-424, 11 March, 2013
DOI 10.5897/SRE12.658
ISSN 1992-2248 © 2013 Academic Journals
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Interaction between suspended and settled solid particles in cassava wastewater

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Accepted 1 February, 2013

Cassava (*Manihot Esculenta*, Crantz) is a very important staple food in most developing countries. During its processing into cassava flour or garri, wastewaters are generated and are indiscriminately discharged into the public sewers or into the environment and in some cases; the fermented wastewater is usually poured into latrines with the aim of degrading sewage. This study is aimed at finding out the interaction between the suspended solids and settled solids of cassava wastewater. Cassava wastewater was collected from a cassava processing plant at Ogige main market in Nsukka town and monitored for 14 days. Half of the samples collected were left unstirred and the other halves were continuously stirred. The parameters monitored include biochemical oxygen demand (BOD_5), suspended solids, coliform, cyanide and pH. Results showed that there was a 73.4, 27.5 and 99.9% reduction in the settled solids for BOD_5, suspended solids and coliform bacteria respectively, for the stirred samples while there was a 97.8, 44 and 99.9% reduction in the settled solids for BOD_5, suspended solids and coliform bacteria respectively, for the unstirred samples. Overall, the unstirred samples performed better than the stirred samples with respect to BOD_5 and SS removal. The result of this work will guide sanitary engineers in the selection of influent parameters for the effective design of treatment units.

Key words: Cassava, wastewater, suspended solids, settled solids, treatment unit.

INTRODUCTION

Cassava (*Manihot Esculenta,* Crantz) is a very important staple food in most developing countries. It has its origin in South America and is extensively cultivated as an annual crop in tropical and subtropical regions of the world for its edible starchy, tuberous root. It is known to be a major source of carbohydrates with Africa being the largest centre of production (Claude and Denis, 1990; Ehiagbonare et al., 2009). It is a major staple food in Nigeria and therefore produces large volumes of wastes that creates environmental nuisance in the region (Mbongo and Antai, 1994; Horsfall et al., 2003; Oboh, 2006). These wastes would even be more problematic in future with increased industrial production of cassava products such as cassava flour and garri. Figure 1 shows the process flow chart for cassava waste water.

As shown in Figure 1, the wastewater extract results from the process of peeling, washing, grinding, and dewatering of cassava tubers. The cassava tubers are peeled, and the discarded peel forms the first stage of the solid waste. Subsequently, when the flesh of the cassava tubers are grated and dewatered, wastewater is obtained. Furthermore, after dewatering, the resulting cassava semi-solid mass is then sieved and the ungrated fibres are then discarded as the final solid waste. Further

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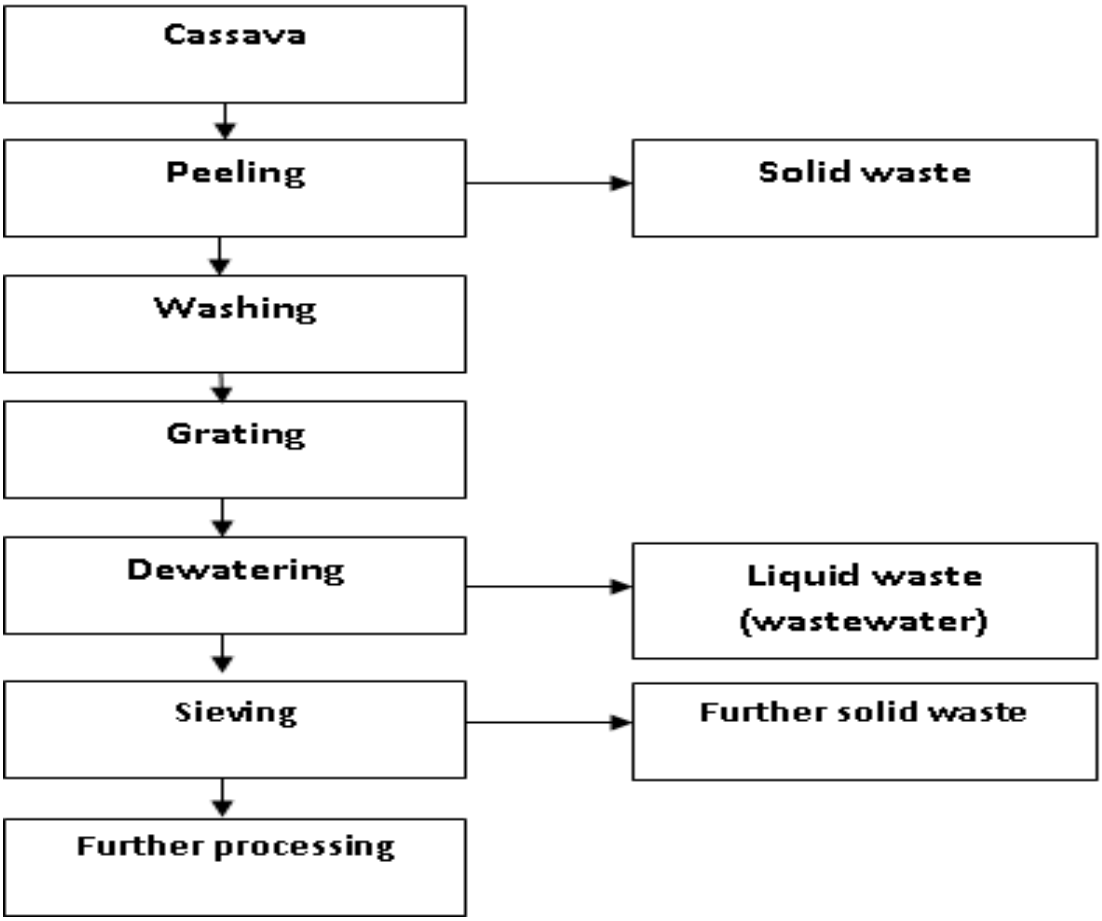

Figure 1. Cassava processing flow chart.

processing involves frying the resulting semi-solid mass. Cassava wastewater, when fresh is a pale yellow turbid liquid with an earthly but inoffensive odour. It contains large floating or suspended solids and very small solids in colloidal suspension (Oboh, 2006). The cassava wastewater may contain oil and grease from the lubricated parts of the grinding machine, in addition to its normal composition of carbohydrates and organic solids. Its processing is generally considered to contribute significantly to environmental pollution and aesthetic nuisance. Cassava wastewater contains carbohydrates (Claude and Denis, 1990); a compound which encourages the growth of bacteria that feeds on it. This growth of bacteria helps to expedite the work of the sanitary engineer that makes use of the bacteria in the treatment of sewage (Obadina et al., 2006). Ubalua (2007) reported that many attempts have been made to aggregate economic value to the liquid residue by considering its utilization as a fertilizer, herbicide, insecticide, nematicide, biosurfactant or substrate for microorganism growth. In rural areas, some of the fermented wastewater is poured periodically into pit latrines and is claimed to aid degradation of bacterial and organics in sewage (Abraham and Kurup, 1996).

Many parameters are employed in the characterization of cassava wastewater because of the presence of organic pollution, notably; suspended solids, biochemical oxygen demand (BOD_5), high values of coliform, pH and cyanide (Marcia and Glaucia, 2006; Ubalua, 2007). Processing of cassava tubers create environmental problems due to indiscriminate discharge of their effluents on land, streams, lakes and rivers. Its high BOD values and cyanide content render it very hazardous to aquatic life and human users. Fermented cassava wastewaters are usually discharged from individual homes in little volumes, yet for several community members practising fermentation it could constitute a heavy pollution on the receiving waters.

BOD_5 is a chemical procedure for determining how fast biological organisms use up oxygen for the decomposition of the organic matter in wastewater. It is used as a measure of wastewater strength and process performance (Clair et al., 2003). The number of faecal coliforms in wastewater effluents is a reliable measure of

its general bacteriological quantity. Information concerning the pH of wastewater can be used in a variety of ways: to determine the freshness of the wastewater; for effective corrosion control; to determine the rule of sludge digestion; to determine the type and amount of chemicals to be used in chemical coagulation for effective and complete coagulation to occur (Lenore et al., 2003). Cyanide in particular is a very toxic compound that has the potential to render soil unproductive because of its acidic nature (Rossling, 1988; Marcia et al., 2006; Ubalua, 2007).

Improper treatment of cassava wastewater as a result of carelessly discharging it into water bodies or soil causes serious environmental pollution and foul odour leading to contamination of surface and underground water and soil (Aisien, et al., 2010). Sometimes, cassava tubers are fermented in streams and ponds, upstream of drinking water points (Oboh, 2006). Okafor et al. (1998) in a report affirmed that suspended solid particles are important as pollutants and pathogens are carried on the surface and body of the particles. The smaller the particle size, the greater the surface area per unit mass of particle, and so the greater the pollutant load that is likely to be carried.

Several attempts have been made by other researchers in some States in Nigeria on the organic matter contained in cassava wastewater and the findings have been adequately used (Oboh, 2006; Okafor et al., 1998; Obadina et al., 2006; Ubalua, 2007; Ehiagbonare et al., 2009). For example, Oboh (2006) discussed extensively on the liquid wastes obtained from the processing of cassava into various end products. Okafor et al. (1998) also stated that treated cassava wastewater can be held in tanks in which organic matter and suspended solids are allowed to settle before being used for irrigation. Obadina et al. (2006), reacting to the importance of suspended and settleable solids, disclosed that the small portion of suspended and settleable solids in cassava wastewater are highly useful in its effects. Ubalua (2007) expressed that this organic matter generally consists of carbohydrates and exists both in suspension and in solution. According to him, the ones in suspension are further subdivided into suspended solids and settleable solids. Ehiagbonare et al. (2009) investigated the effect of cassava effluent on the environment and found out that the effluent had negative effect on plants, air, domestic animals, soil and water from the results of the various parameters investigated.

In spite of all these findings, the treatment and disposal of cassava wastewater from industrial sources is still a major problem in Nigeria. This is because cassava wastewater disposal is done improperly and allowed to accumulate overtime. Most of the cassava wastewater arising from processing ends up with domestic waste while others percolate into the soil. Some of these cassava wastewaters are carried in suspension, others go into solution, while others have become so finely divided that they exist in colloidal state. Hence, the objectives of this study are as follows:

1. To determine the relationship that exists between the suspended solid particles and non- colloidal solid particles in cassava wastewater.
2. To investigate the characteristics of cassava wastewater with respect to BOD, coliform, cyanide, suspended solids and pH.
3. To assess level of pollution of the suspended solids and settleable solids of the cassava wastewater and compare the efficiencies of degradation in the stirred and unstirred batch reactors.

MATERIALS AND METHODS

Source of sample and location

The representative samples for the cassava wastewater used in this study were obtained from a garri processing plant located at Ogige Main Market in Nsukka town, Enugu State, Nigeria. The industry is a small one. Hence, the average annual production and age of the wastewater generated per day was not estimated.

Laboratory set-up

The cassava wastewater extract was poured into six plastic buckets, labelled A, B, C, D, E, and F. These buckets contained nine litres of the cassava wastewater extract each and were fitted with plastic taps at different levels on the container. The tap for A was fitted at the bottom level of the container, B was fitted at the centre, and C was fitted at the top level. The same goes for D, E, and F. The tap for D was fitted at the bottom level, E was at the centre and F was at the top. A, B and C were level in a quiescent state while D, E, and F underwent a complete mix flow throughout the duration of the experiment. The mechanical stirring of D, E, and F was done with the help of a magnetic stirrer put in each of the buckets. These buckets were placed on top of a magnetic stirrer hot plate which uses electricity to create a magnetic field that rotates the magnetic stirrer which completely stirs the contents of D, E, and F.

Sampling technique

The samples of the cassava wastewater were collected in replicates from each of the buckets through the taps at 0 h, 6 h and days 1, 3, 5, 8, 14 with a clean container. The sampling equipment and techniques were selected so that changes in the constituents to be analyzed will not occur between the time the samples are collected and the time they are analyzed. Hence, period or interval between the time of collection of the sample and the time the test was carried out was regulated. Also, unused samples were preserved in the refrigerator to avoid any chemical activity like oxidation or degradation as the case may be. Five major experiments were conducted for each of the samples. Each sample was thoroughly shaken and analysed at room temperature (25°C) for determination of five day BOD_5, suspended solids, and coliform following the procedures outlined in the standard methods (APHA, 1989). Total cyanide and pH were also determined.

Determination of biochemical oxygen demand (BOD)

This was done by adopting the Winker's azide method. In this

procedure, 2 ml of $MnSO_4$ (prepared by dissolving 22.5 g of $MgSO_4$ in distilled water and diluting to 1 L) was pipette into each of the twelve 300 ml BOD bottles and 2 ml of alkaline iodide azide was also pipette into the BOD bottles. 1 ml of the cassava waste water was added to the twelve BOD bottles, six for incubation and other six for the determination of the initial DO in the mixture. This is to introduce the biological population capable of oxidising the organic matter. The contents of the bottles were mixed and kept to settle. After settling, the supernatant was carefully poured off and 2 ml concentrated H_2SO_4 was added. Titration was done with sodium thiosulphate using starch as an indicator. The colour change observed was from pale yellow to black (after addition of indicator) to colourless. After 5 days incubation oxygen demand was also determined for other six bottles by Winkler azide method. The BOD_5 (mg/1) was calculated thus:

$$BOD_5\left(mg/1\right)=\frac{D_1-D_2}{p}$$

where: D_1 = DO of diluted sample 15 min after preparation
D_2 = DO of diluted sample after incubation
P = Decimal fraction of sample used.

Determination of suspended solids (SS) by gravimetric method

Six different samples were collected from the buckets containing the cassava wastewater. Beakers and filter papers used in the experiment were oven-dried at 105°C for one hour. The beakers with the filter papers inside were placed in desiccators to cool. The empty beakers with filter paper were weighted on an electronic weighing machine and recorded. 10 ml of each of the samples was taken and filtered, using separate filter papers (the weighted ones) and a vacuum device. The filter papers were returned into the beaker and dried again to a constant weight. They were cooled slightly, and placed in the dessicator to cool and then reweighed. The difference in weight was recorded as suspended solid. The SS (mg/l) was calculated thus:

$$SS\left(mg/1\right)=\frac{weight\ of\ \ SS\ \left(mg\right)\times 1000}{ml\ of\ sample}$$

Determination of coliform by multiple-tube fermentation technique

Dilution water was prepared by adding 1.25 ml of phosphate buffer solution to 1000 ml of distilled water. 43.5 g of Maconkey broth was suspended in 531.25 ml of distilled water. 10 and 5 ml of the medium were then distributed in fermentation tubes with inverted Durham tubes. The fermentation tubes were sterilized by autoclaving at 15 lbs pressure (121°C) for 15 min. The tubes were cooled before inoculation. 18-10 ml portions of the sample was inoculated in the fermentation tubes containing the 10 ml medium and 18-1 ml and 18-0.1 ml portions of the sample was inoculated in the fermentation tubes containing 5 ml medium. The fermentation tubes were arranged in a test tube rack and placed in a water bath for 48 h. The tubes which show gas in the tubes were recorded as positive tests and the absence of gas formation recorded as negative tests. From the most probable number (MPN) table, the number of coliforms corresponding to positive tubes were read and recorded.

Determination of cyanide by the titrimetric method

10 ml of the sample was transferred to a measuring cylinder. The sample was then diluted to 250 ml (each) for the titrations and put in a conical flask. 0.5 ml of the indicator solution was added. The pH was adjusted by adding 4 ml of NaOH solution and shaken thoroughly. The mixture was titrated with standard $AgNO_3$ solution to the first change in colour from a colourless to canary yellow. A distilled water blank containing the same amount of NaOH solution and indicator as in the sample was titrated. The same amount of indicator was used for all the titrations to give the best result. The titration was difficult for the first few trials, because of high limit of sensitivity and indistinct colour change reflected in high blank values. As the end point was reached, the blank titrations decreased and precise values were obtained accordingly. The CN (mg/L) was calculated thus:

$$CN\left(mg/l\right)=\frac{\left(A-B\right)\times 1000}{\text{ml of original sample}}\times\frac{N}{\text{ml of sample}}$$

where:
A = volume of $AgNO_3$ for titration of sample
B = volume of $AgNO_3$ for titration of blank.
Oxidising agents such as chlorine and nitrites decompose most cyanide.

Determination of pH

The pH of the water samples was determined using the Hanna microprocessor pH meter. The electrode of the pH meter was carefully standardized with a buffer solution of pH range between 4 to 9 and dried with tissue patter. The electrode was dipped into a beaker containing a small amount of sample and the beaker shaken gently. Values from the pH meter were read off and recorded. The electrode and beaker used were rinsed with distilled water before subsequent addition of samples to the beaker.

RESULTS

The graphs plotted from the results of the tests conducted are shown in Figures 2 to 11. They illustrate the variations of the concentration of BOD_5, suspended solids, coliform, cyanide and pH with time.

Statistical analysis

The statistical significance or non-significance to measures the strength and the direction of the linear relationship between the time (days) and parameter sample tests was established by applying the linear correlation coefficient, r as shown in Table 1.

$$r=\frac{n\sum xy-\left(\sum x\right)\left(\sum y\right)}{\sqrt{n\left(\sum x^2\right)-\left(\sum x\right)^2}\sqrt{n\left(\sum y^2\right)-\left(\sum y\right)^2}}$$

where: n = sample size.
x = time (days) and
y = time sample (unstirred and stirred)

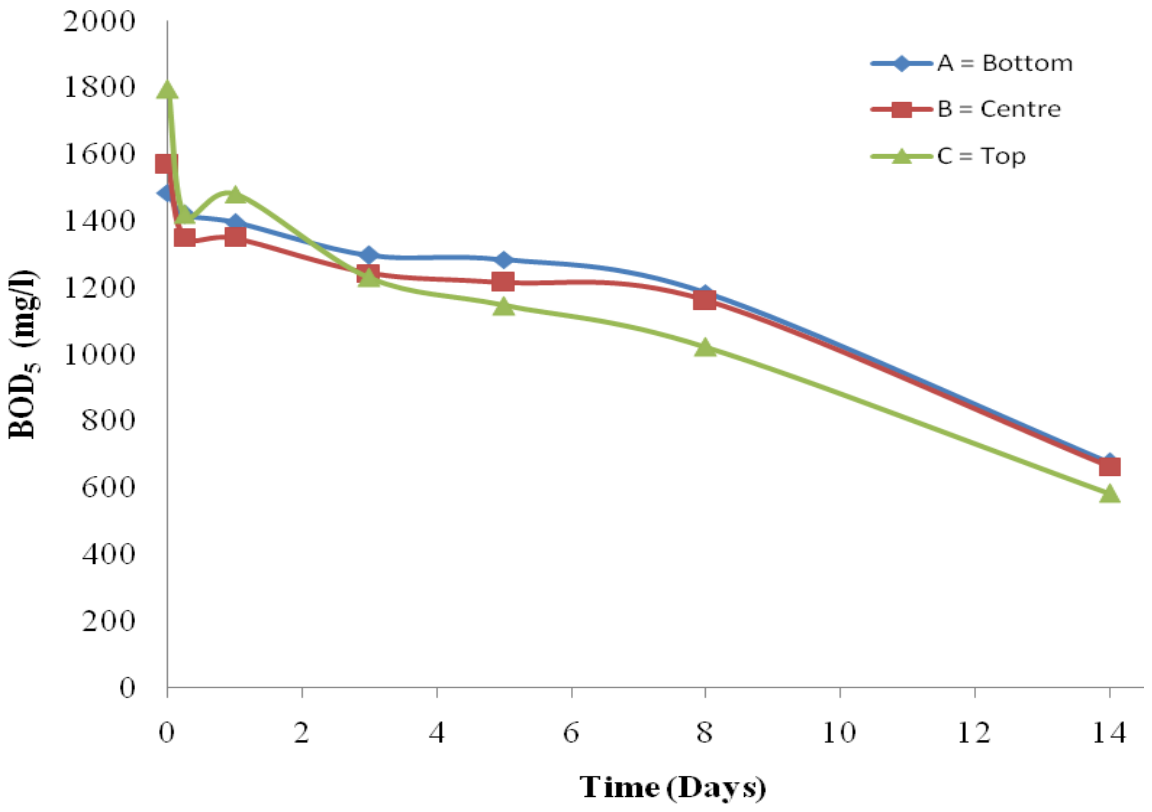

Figure 2. Variation of BOD with time for unstirred samples A, B, C.

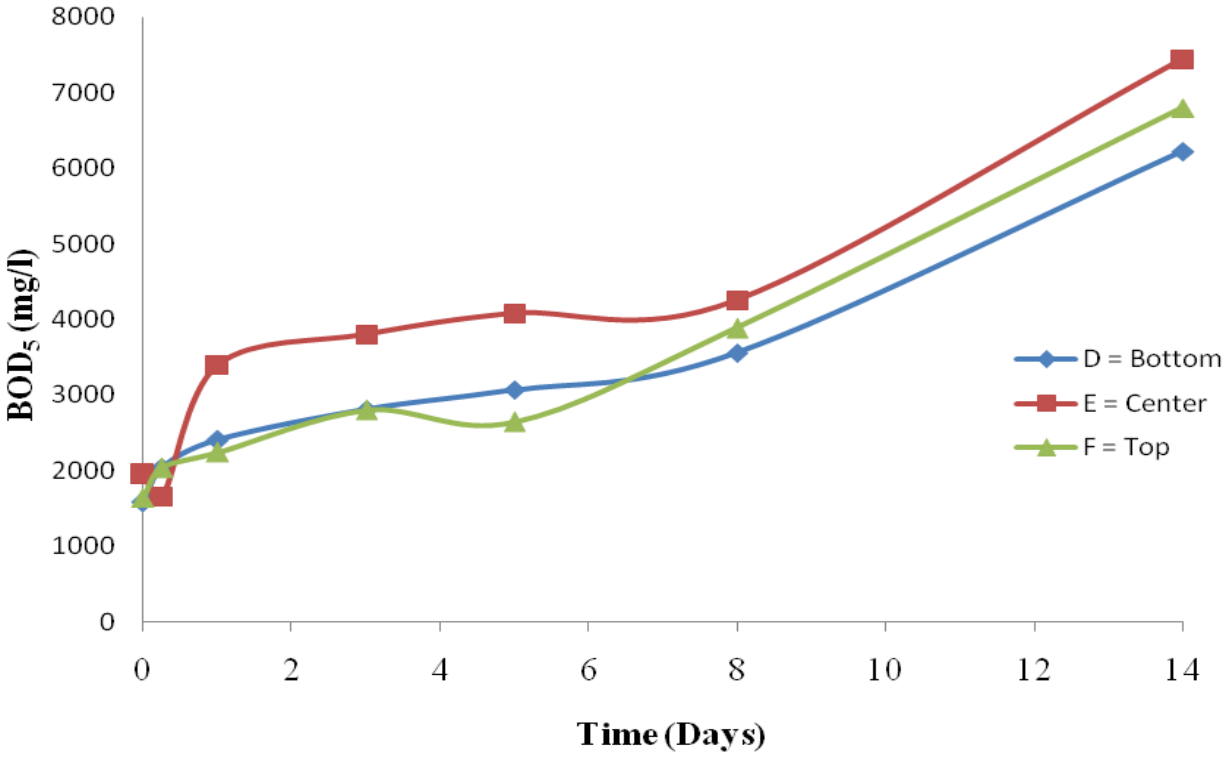

Figure 3. Variation of BOD with time for unstirred samples D, E, F.

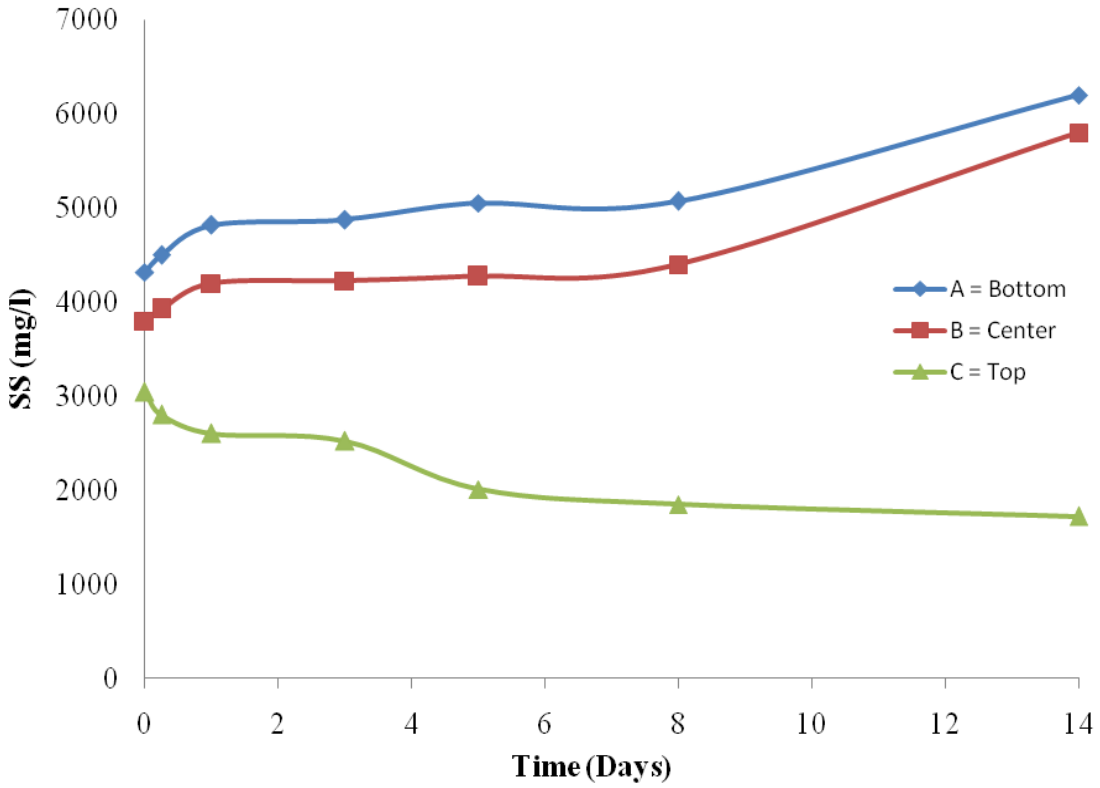

Figure 4. Variation of suspended solid with time for unstirred samples A, B, C.

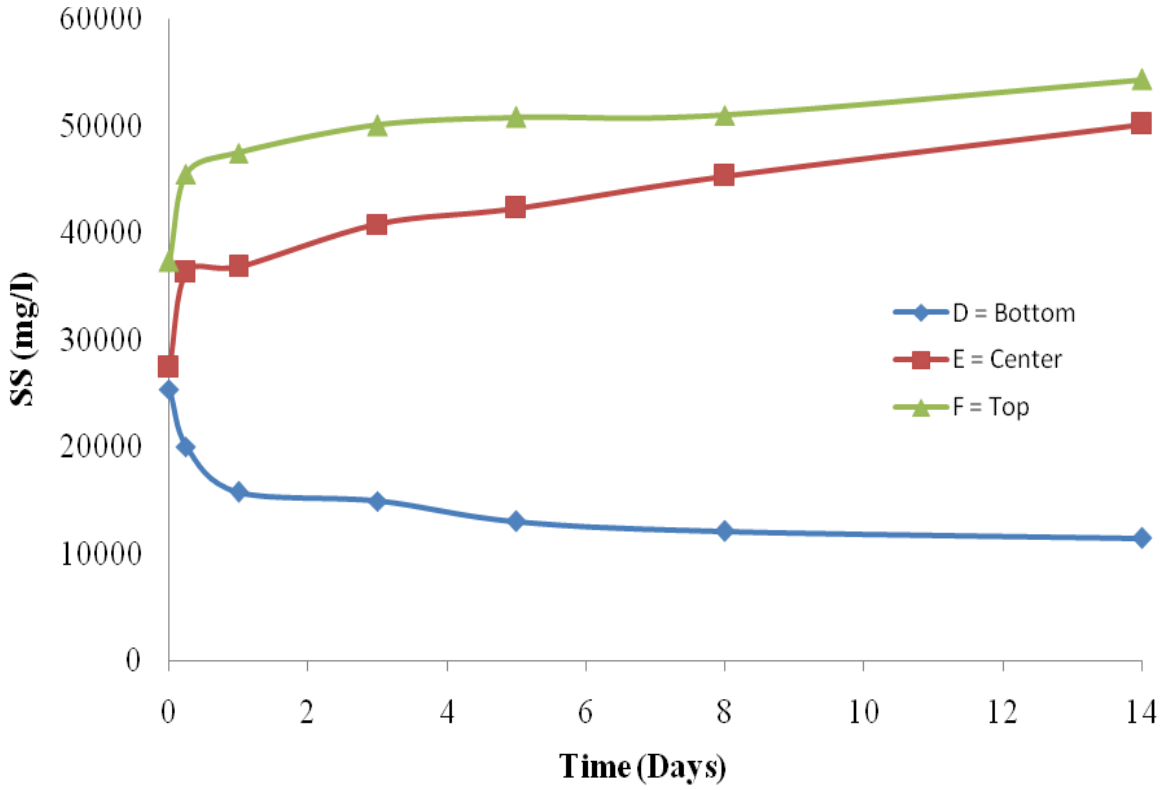

Figure 5. Variation of suspended solid with time for stirred samples D, E, F.

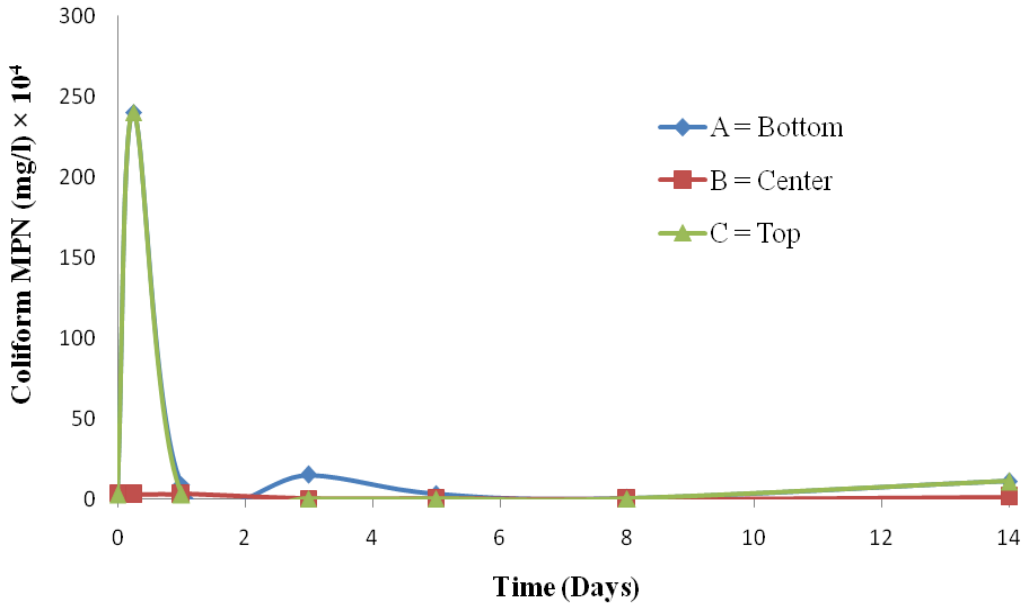

Figure 6. Variation of coliform MPN with time for unstirred samples A, B, C.

Table 1. Values of r for all the parameters tested in the cassava wastewater.

Sample	BOD_5	SS	Coliform	Cyanide	pH
		Unstirred sample			
Bottom (Sample A)	-0.9675	0.9549	-0.3595	-0.9078	0.8210
Middle (Sample B)	-0.9492	0.9355	-0.5861	-0.9445	0.8331
Top (Sample C)	-0.9482	-0.9095	-0.3394	-0.9517	0.8971
		Stirred sample			
Bottom (Sample D)	0.9755	-0.7546	-0.3699	-0.9567	0.9568
Middle (Sample E)	0.9489	0.8905	-0.4928	-0.9409	0.9888
Top (Sample F)	0.9709	0.7691	-0.4297	-0.8445	0.9894

DISCUSSION

Characteristics of cassava wastewater from the experiment

Figures 2 and 3 show the graphs of BOD_5 for unstirred and stirred samples. These values give indication of the pollution load from cassava wastewaters discharged into the septic tanks or receiving streams. At the end of the 14 days, unstirred samples of the cassava wastewater showed a reduction in BOD_5. This shows that the oxygen available in the water is not completely consumed by the bacteria and the dissolved oxygen (DO) levels increased, indicating a small amount of organic pollution, where fish and other aquatic organism may survive in the water. However, the stirred samples of the cassava wastewater showed an increase in BOD_5. When the BOD increases, there is an increase in the organic pollution and consequent decrease in DO. When all DO in the wastewater is used up, anaerobic conditions occur and objectionable odours ensue. Most fish and aquatic organisms cannot survive in the water (Henry and Howeler, 1996).

The suspended solids values are greater at the bottom, for the unstirred batches, and at the top (for the stirred batches). The suspended solids settle with age, and more degradation occurs at the top giving lower values of suspended solids because of the settling effect. But continuous stirring of the cassava wastewater causes the suspended solids to gravitate towards the top giving higher values and leaving the bottom with the lowest values. Variation in coliform was very erratic throughout the experiment especially for the stirred samples. The irregular trend would possibly be attributable to the interaction between the coliforms in the cassava wastewater. As shown in the coliform variation graphs (Figures 6 and 7), there is an initial period of what appears to be little or no growth called the lag phase,

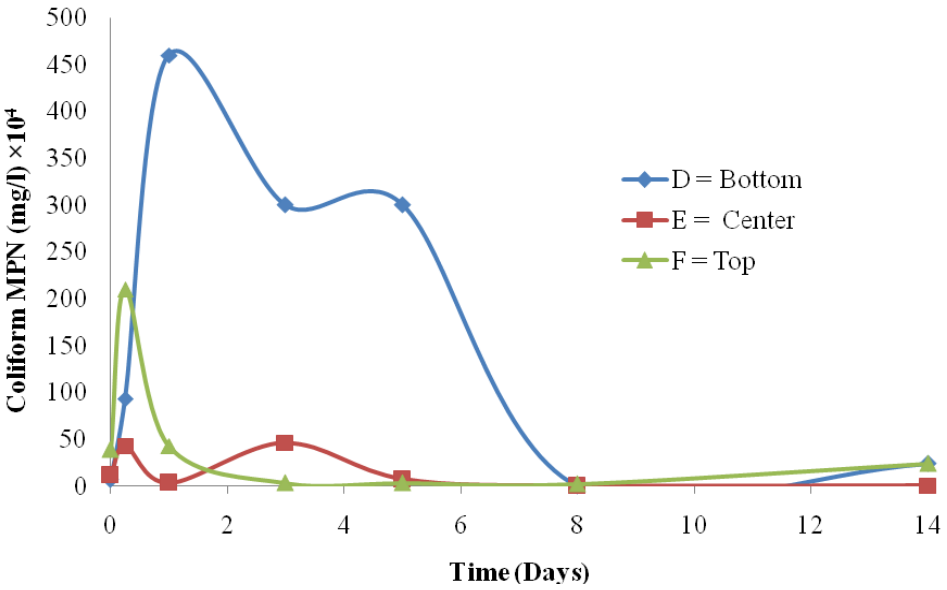

Figure 7. Variation of coliform MPN with time for stirred samples D, E, F.

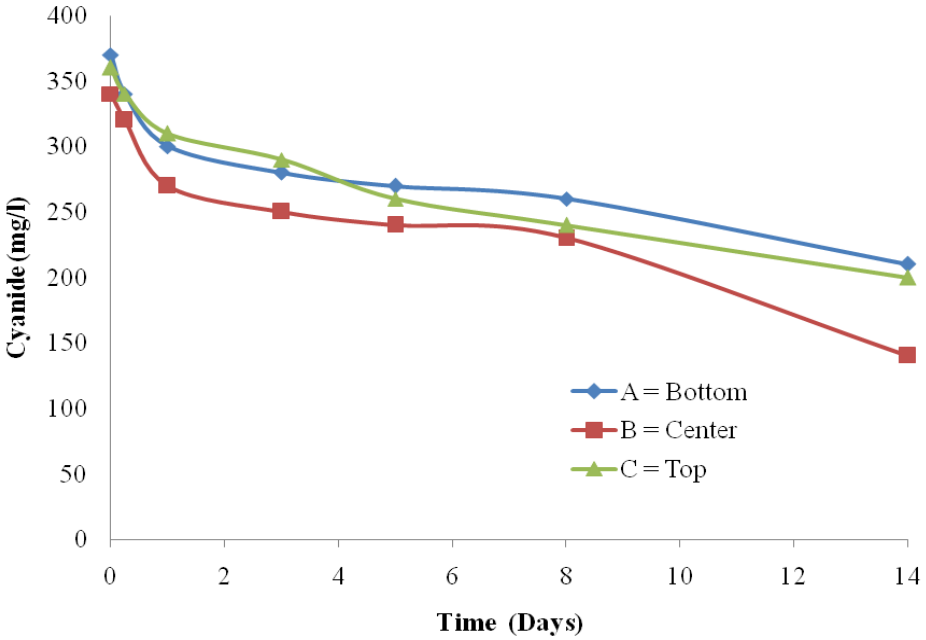

Figure 8. Variation of cyanide with time for unstirred samples A, B, C.

then the rapid exponential growth occurs (called the experimental growth or log phase. This phase continues until stabilization at a maximum population is reached (called the stationery phase), then followed by a declining or death phase. The death or declining phase is reached when the death rate starts to exceed the growth rate. In addition to the depletion of nutrients, toxic-by products of all metabolisms can build up in the environment, inhibiting further growth (Henry and Howeler, 1996). The level of interaction and types of coliform bacteria were not established during this preliminary investigation.

The cyanide values are greater for the unstirred samples than the stirred samples as shown in Figures 8 and 9, but all values decreased as the days went by. Because the CN present in the wastewater evaporates with time as noted earlier. Sample B (Centre), unstirred,

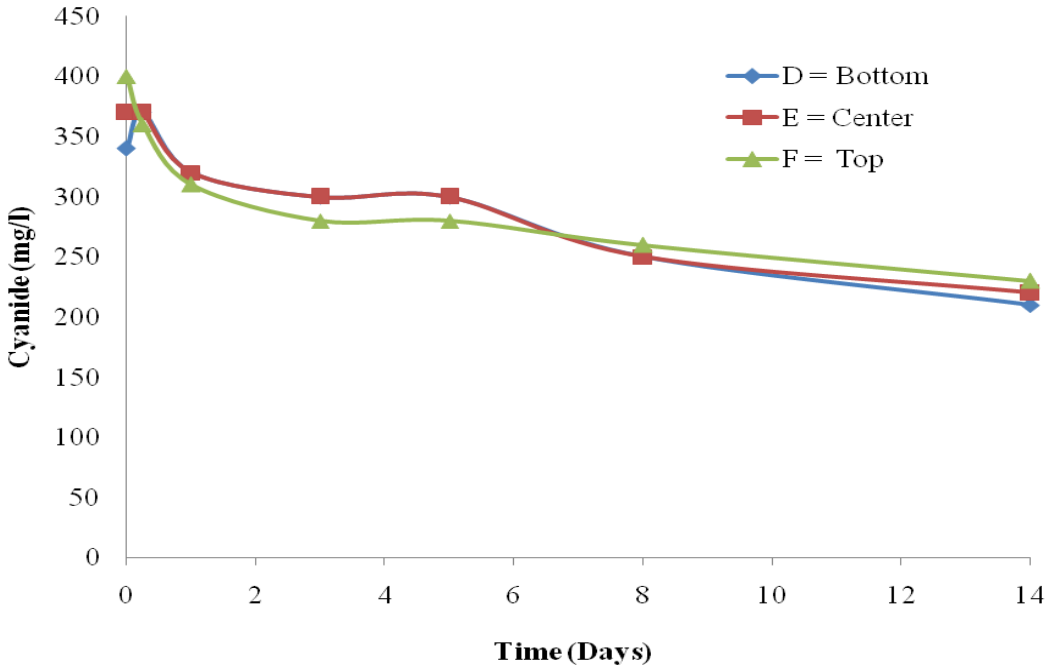

Figure 9. Variation of cyanide with time for stirred samples D, E, F.

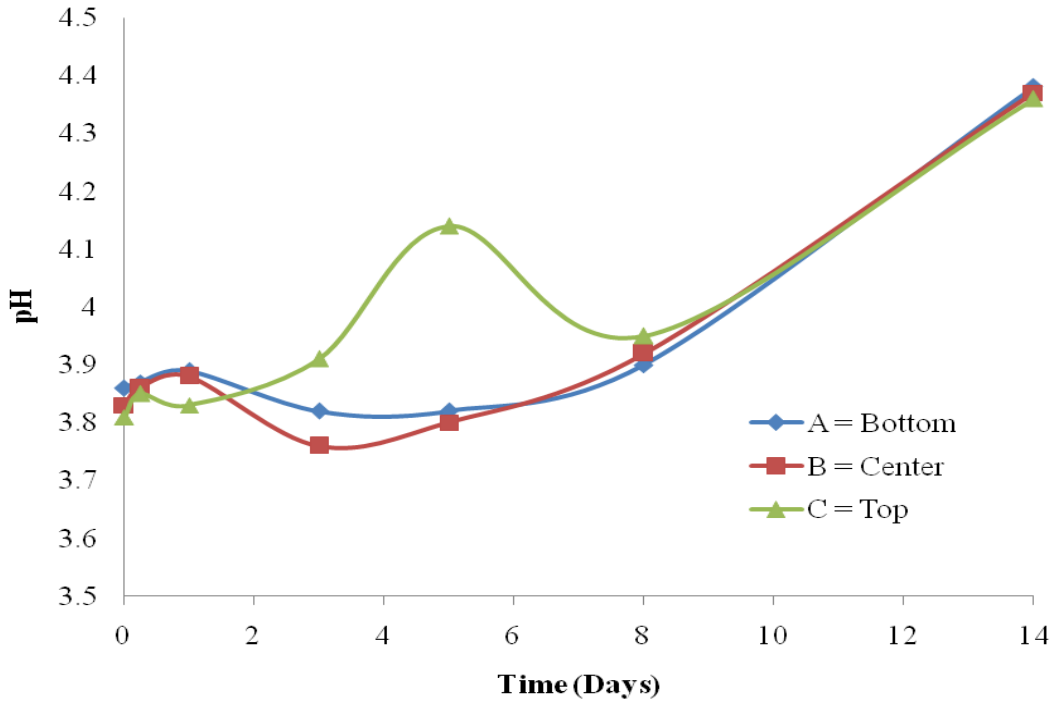

Figure 10. Variation in pH with time for unstirred samples A, B, C.

showed a sharp increase in cyanide value. This could be due to differences in temperature and pH fluctuations. The pH test graphs (Figures 10 and 11) showed a trend that one can state without much error that for all samples there is a steady shift and decrease in acidity from the 0 h to the 14th day. The cassava wastewater generally

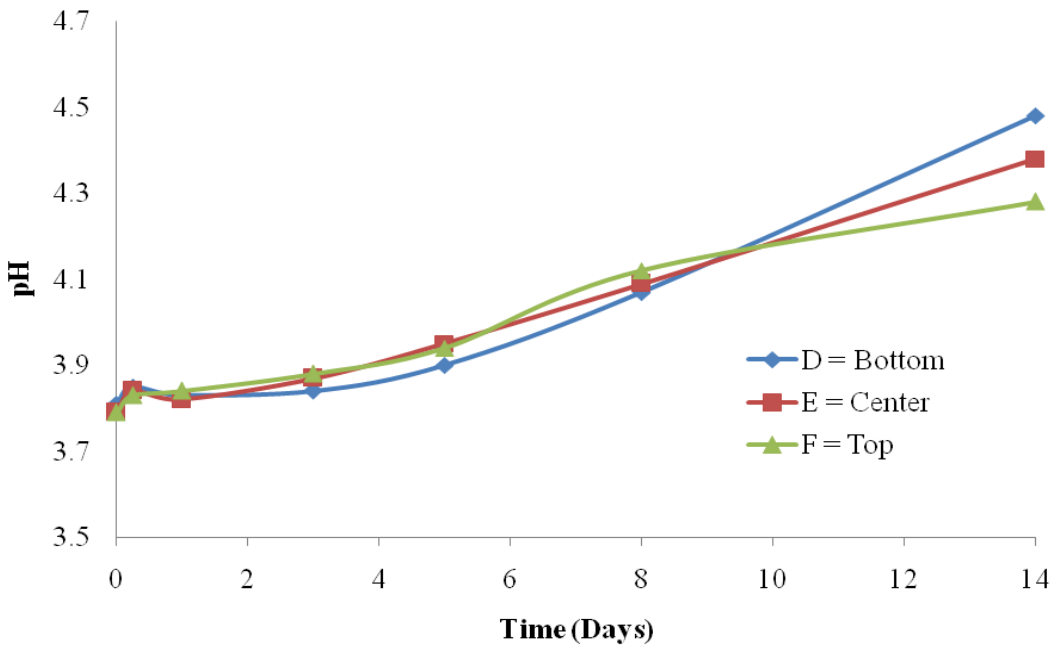

Figure 11. Variation in pH with time for stirred samples D, E, F.

Table 2. Comparison between the performance of the suspended solids and settled solids in the batch reactors for the cassava wastewater extracts.

Parameter	Stirred		Unstirred	
	Suspended solids	Settled solids	Suspended solids	Settled solids
	Reduction %	Reduction %	Reduction %	Reduction %
BOD_5 (mg/L)	82.6	73.4	86.0	97.8
SS (mg/L)	64.4	27.5	64.8	44.0
MPN (mg/L)	99.9	99.9	99.9	99.9
Cyanide (mg/L)	61.0	76.2	70.5	76.2
pH	12.3	17.6	13.4	14.7

shows acidic behaviour.

As presented in Table 1, the value of *r* is such that -1 < *r* < +1. The + and - signs are used for positive linear correlations and negative linear correlations, respectively. Positive values indicate a relationship between *x* and *y* variables such that as values for *x* increase, values for *y* also increase. Negative values indicate a relationship between *x* and *y* such that as values for *x* increase, values for *y* decrease. All the stirred samples for the BOD_5 tests: D, E and F have a positive value of r close to 1 which indicates a strong correlation between data set x and y. On the other hand, the unstirred samples had negative values closer to -1 indicating that, time x and data set for unstirred sample y has a strong negative linear correlation. For the suspended solids, all the samples had a strong correlation with time except for sample C at the top and sample D at the bottom. This indicate that continuous stirring of the cassava wastewater causes the suspended solids to gravitate towards the top giving higher values and leaving the bottom with the lowest values unlike when the sample was left unstirred and there was settlement at the bottom. The negative values of r, for coliform and cyanide for both stirred and unstirred samples, corroborate the variation in coliform which was very erratic throughout the experiment. The positive r values for pH in all samples show a strong correlation between time, x, and y for unstirred and stirred samples. This implies that as the time increases, the pH of the wastewater increases thus, indicating a gradual shift from acidity to alkalinity.

Interaction between the suspended solids and settled solids cassava wastewater

As shown in Table 2 for the parameter variation with time

for the cassava wastewater for the stirred and unstirred samples, the settleable solids are grouped as samples gotten from the bottom, while the suspended solids are grouped as the samples from the top and the centre. For all the stirred samples, there is a significant suspended solids reduction of 82.6, 64.4, 61.0 and 12.3% for BOD_5, SS, Cyanide and pH over the 14 days of the study. For all the unstirred samples, the suspended solids reduction are 86.0, 64.8, 70.5 and 13.4% for BOD_5, SS, cyanide and pH respectively. The optimum mixture for BOD_5 and SS removal for both stirred and unstirred samples is 4.6 and 0.4% respectively. This suggests that cassava wastewater degrades itself when left untouched in a container. The highest percentage removal of BOD_5 and coliform was achieved in the settled unstirred sample corresponding to the efficiencies of 97.8 and 99.9% respectively. However some of the other reactors of both the stirred and unstirred sample still achieved high efficiencies with respect to these five parameters.

Comparison between the settled and suspended solids in cassava wastewater with respect to reduction in BOD_5, SS, coliform, cyanide and pH are shown in Table 2. Initial pH of the cassava wastewater had a strong effect on the cyanide production. As the pH increased, the cyanide production decreased. The highest specific cyanide production potential of 400 mg/L was obtained at an initial pH of 3.8 whereas the lowest specific cyanide production potential of 210 mg/L was obtained at an initial pH of 4.5. This is in close agreement with Khanel and Velter (2006) who found out that a pH of 2.0 to 3.0 was optimum pH for cyanide production.

Conclusion

An assessment of the level of pollution of the suspended solids and settleable solids of the cassava wastewater has been presented. The following results were obtained:

1. The unstirred samples performed better than the stirred samples with respect to removal of BOD_5, and SS.
2. The optimum percentage of cassava wastewater for maximum rate of degradation was 4.6 and 0.4% for stirred and unstirred samples with respect to BOD_5 and SS removal.
3. Although the optimum percentage for BOD_5 and coliform bacteria removal were 97.8 and 99.9% for the settled solids in the unstirred samples, other samples also gave high removal efficiencies.

The issue of indiscriminate discharge of effluents from processing of cassava tubers poses a major challenge to environmental engineers and if the solution is not properly addressed, it can ruin aquatic life and even human users due to its high BOD_5 and cyanide content, causing much environmental problems. This study has revealed that the suspended and settleable solids of cassava wastewater are indeed important and the interest in their relationship will help in the advancement of the treatment process.

REFERENCES

Abraham M, Kurup GM (1996). Bioconversion of tapioca (Manihot esculenta) waste and water hyacinth (*Eichhornia crassipes*) influence of various Physico-chemical factors. J. Ferment. Bioeng. 82:259-263.

Aisien ET, Gbegbaje-Das E, Aisien FA (2010). Water Quality Assessment of River Ethiope in the Niger-Delta coast of Nigeria. Elect. J. Environ. Agric. Food Chem. 9(11):1739-1745.

APHA (1989). Standard methods for the examination of water and wastewater, 17th edition.

American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington D.C.

Clair N, Derry L, Gene F (2003). Chemistry for environmental engineering and science, 5th edition, New York: McGraw-Hill.

Claude F, Denis F (1990). African Cassava Mosaic Virus: Etiology. Epidemiol. Control Plant Dis. 64(6):404-411.

Ehiagbonare JE, Enabulele SA, Babatunde BB, Adjarhore R (2009). Effect of cassava effluent On Okada denizens. Sci. Res. Essay 4(4):310-313.

Henry G, Howeler R (1996). Cassava in China in an era of change. A CBN case study with farmers and processors. Working Document No. 155. CIAT, Cali, Columbia p. 18.

Horsfall M, Abia AA, Spiff AI (2003). Removal of Cu (II) and Zn (II) ions from wastewater by cassava (*Manihot esculenta* Cranz) waste biomass. Afr. J. Biotechnol. 2(10):360-364.

Khanel Y, Velter S (2006). Toxfags for cyanide. Agency for Toxic substances and disease registry.

Lenore SC, Arnold EG, Andrew DE (2003). Standard methods for examination of water and wastewater, 20th Edition, Washington D. C. American Public Health Association. Stevens institute of technology.

Marcia N, Glaucia MP (2006). Production and properties of a surfactant obtained from *Bacillus subtillis* grown on cassava wastewater. Bioresour. Technol. 97(2):336-341.

Mbongo PN, Antai SP (1994). Utilization of cassava peels as substrate for crude protein formation. Plants Foods Hum. Nutr. 46:345-351.

Obadina AO, Oyewole OB, Sanni LO, Abiola SS (2006). Fungal enrichment of cassava peels proteins. Afr. J. Biotechnol. 5(3):302-304.

Oboh G (2006). Nutrient enrichment of cassava peels using a mixed culture of saccharomyces cerevisae and *Lactobacillus* spp. Solid media fermentation. **Electr. J. Biotechnol. 9(1):46-49.**

Okafor N, Umeh C, Ibenegbu C (1998). Amelioration of garri, a fermented food derived from cassava, *Manihot esculenta* Crantz, by the innoculation into cassava mask of microorganisms simultaneously producing amylase, linamarase, and lysine. World J. Microbiol. Biotechnol. Press. 14:835-838.

Rossling DH (1988). Cassava toxicity and food security. 2nd ed. A report of UNICEF, African Household Food Security Programme International Child Health Unit, University Hospital Uppsala. pp. 40-43.

Ubalua AO (2007). Cassava waste: treatment options and value addition alternatives. Afr. J. Biotechnol. 6(18):2065-2073.