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Prospects of Combined Peroxide Oxidation, Aeration and Adsorption-Filter Treatment Processes in Abatement of Pollution Characteristics in Cassava Processing Wastewater

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Abstract

The study investigated the efficacy of a treatment sequence consisting of a peroxide oxidation, aeration and adsorption-filtration at four different carbon depths in controlling pollution parameters from cassava processing wastewater. Analysis of results obtained revealed that concentration of selected physico-chemical parameters of effluent drawn from the established treatment lines were all within the Federal Environmental Protection Agency's standards for discharge to water bodies with the exception of Total Suspended Solids (TSS). Statistical analysis of results using ANOVA showed that the effect of carbon depth on concentration of considered parameters was not significant (p 0.05) for iron, manganese, calcium and zinc while all other parameters were significant. The separation of effluent parameter means done by Duncan multiple range tests also revealed that the means of values from the four columns were not significantly ($p > 0.05$) different for iron, manganese, mercury, nickel, zinc and phenol ions while those for colour, nitrate, TDS and TSS solids were all significantly different. All other considered parameters however had two or more parameters sharing mean values that were grouped as not being significantly different. The particle index comparison for the treatment processed revealed that the dual filter media columns exhibited a more stable working when it came to turbidity treatment. The study concluded that the effluent from the sand filter and 5 cm carbon depth dual media treatment process could be safely discharged to watercourse or used for irrigation purposes.

Keywords: Aeration, Cassava, Filtration, Hydrogen peroxide, Wastewater

Introduction

In most developing countries, the issue of land and water pollution resulting from activities of large cassava processing communities has been given very little attention due to the uncoordinated nature of the industry. In cassava processing communities, huge quantity of wastewater and solid waste are generated and could constitute an environmental menace where not adequately managed. In Nigeria, high levels of cassava effluent are produced daily and indiscriminately drained onto nearby, streams, rivers and agricultural lands, thereby, constituting a serious environmental hazard. Not only does the effluent result in a strong stench, it could also result in loss of aquatic life due to its toxic nature. More recently the problem of effluent from processing operation and their disposal has gained public recognition. In many areas of the world, especially the developing countries, these environmental issues are the same (Okonko *et al*., 2006; Shittu *et al*., 2007). In South Western Nigeria, cassava mill is one of the major industries and the mills are on many occasions sited in areas where the effluent is capable of causing pollution on arable lands and fresh water sources. According to Izonfuo *et al.* (2013) and Ehiagbonare *et al.* (2009) evidence have shown that concentration of contaminants present in soil samples obtained around cassava processing sites were higher than recommended values.

Pollution from cassava processing wastewater has been observed to be responsible for a number of agricultural and environmental issues which include inducement of stresses and delay in germination of plants (Nwaogu *et al.,* 2011), mutation of plant genes (Olorunfemi *et al.,* 2011) etc. According to Wade *et al.* (2002) and *Ariyomo (2017)* effluent from cassava processing has also been observed to have toxic effects on aquatic life. There is therefore the need for treatment of wastewater from agricultural processing activities before they are discharged into the water courses or open fields in order to reduce potential environmental hazards as suggested by Ewemoje *et al*., (2011).

Water is a resource that is unique to the earth and also crucial to the existence of life. Many authors have argued that access to clean water is gradually dwindling due to continuous pollution of existing water bodies. Over the last century, continued population growth and industrialization have resulted in the degradation of various ecosystems on which human life relies on (Chan *et al.,* 2009). As the world population increases the availability of clean water becomes a critical issue. According to Rowell (2006) it is estimated that by the year 2025, there would be an additional 2.5 billion people on the earth that will live in a region already lacking sufficient clean water. The study is therefore aimed at establishing four different treatment lines and comparing the efficiencies of these four treatment sequences to confirm if any of them could offer a viable option for recycling wastewater from cassava processing activities for use in irrigation and safe discharge to water courses.

Materials and Methods

The treatment process consisting of a peroxide oxidation process followed by an aeration process then simultaneous filtration and adsorption-filtration processes was set up at the Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria. The schematic of the treatment process employed is shown in Figure 1. Wastewater used for the treatment process was collected from a cassava processing industry in airtight opaque containers and kept in ice bag while transporting to maintain biological state at source.

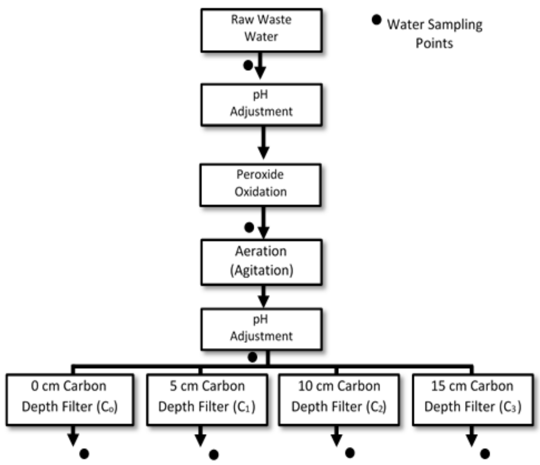


Figure 1: Schematic diagram of treatment process

Peroxide Oxidation Process

The collected wastewater was adjusted to a pH range between 10 and 11 by adding 0.5 M of NaOH to the oxidation tank in order to have the CN content in solution as suggested by Caruso (1995) in order to have 99% CN remain in solution. Hydrogen peroxide at 50% concentration was then added at 0.025 ml/l of wastewater (about 0.5 g H_2O_2/g of CN^-) for the oxidation process. The wastewater was thereafter left for a period of 3 hrs to ensure a reasonable level of oxidation and cyanide destruction. A sample of the effluent from the aeration chamber was obtained in a clean sterilised PET bottle and stored in an ice bucket to preserve it until end of the treatment process.

Aeration Process

After the peroxide oxidation process an aeration chamber incorporating a vertical axis paddle aeration system powered by a fractional power electric motor with dimensions as shown in Figure 2 was used in the aeration process.

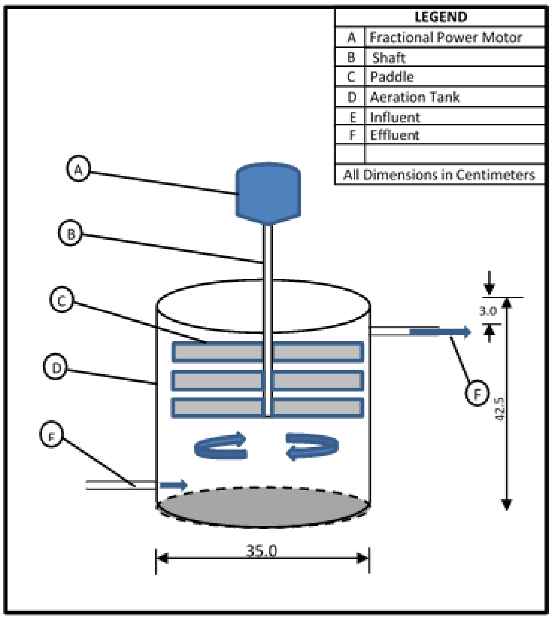


Figure 2: Aeration chamber

The wastewater was agitated by the aerator's paddle system for a period of 1 hour at a speed of 65 rpm as recommended by Omotosho (2017). The effluent in the chamber was displaced from by fresh effluent which was released into the chamber from the inlet of the aeration chamber to effect slow displacement at a rate of 0.25 l/min to ensure that the system does not become overloaded. A sample of the effluent from the aeration chamber was obtained in a clean sterilised PET bottle and also stored in an ice bucket to preserve it until end of the treatment process.

Filtration and Adsorption-Filter Processes

Three adsorption-filtration dual media columns and one control column with external dimensions 0.18 m × 0.18 m square base and 0.65 m height were constructed from 4 mm thick transparent Perspex materials and filled with sand and charcoal varied at three different levels. The control was filled with only the washed, graded sand while the three adsorption filter columns (C_1-C_3) were filled with the washed, graded sand (0.5-2.0 mm) and charcoal (50-300 µm) in alternate formation thereby making it a dual media filter. The dimensions and configuration of sand and carbon materials in the columns from bottom to top were:

C_0= 65 cm sand.

C_1= 50 cm sand followed by 5 cm carbon followed by 10 cm sand.

C_2= 45 cm sand followed by 10 cm carbon followed by 10 cm sand.

C_3= 40 cm sand followed by 15 cm carbon followed by 10 cm sand.

The oxidized and aerated wastewater was then introduced simultaneously into the control and dual filter media (Figure 3) columns at a flowrate of 1.0×10^{-2} l/s as recommended for intermediate slow sand filter media by Environmental Protection Agency (1995). Flow was maintained for a period of 6 hrs and filtrate was collected from the bottom of the columns at an interval of 1hr in clean sterilized PET bottles then kept in an ice bucket for preservation before analysis. The experimental procedure was done in 4 replicates. Physical parameters such as colour, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), turbidity, odour, were determined in accordance with WHO/EC combined standards, following the methods described by Ademoroti, (2006). Chemical parameters such as light and heavy metals like Cadmium(Cd), Zinc (Zn), Nitrogen (N), Chlorine (Cl), Phosphorus (P), Iron (Fe), Nickel (Ni), Magnesium (Mg), Manganese (Mn), Mercury (Hg) and Calcium (Ca) were determined by spectrophotometry using AAS machine with HNO_3 as the reagent. Biological parameters such as Biochemical Oxygen Demand (BOD_5) and Dissolved Oxygen (DO) were determined in accordance with WHO/EC combined standards, following the procedures described by Ademoroti (2006). The analysis of cyanide content of the water was carried out with the aid of a spectrophotometer (Spectrumlab 23A) using the alkaline picrate method. The sample was first be subjected to centrifuging at the speed of 4,200 rpm for about 6 min. The obtained clear supernatant was separated and used for the test using a spectrophotometer at the recommended wavelength and pH range. Blanks which contained pure distilled water were also placed together with the samples in the spectrophotometer, these were used for calibration and quality check.

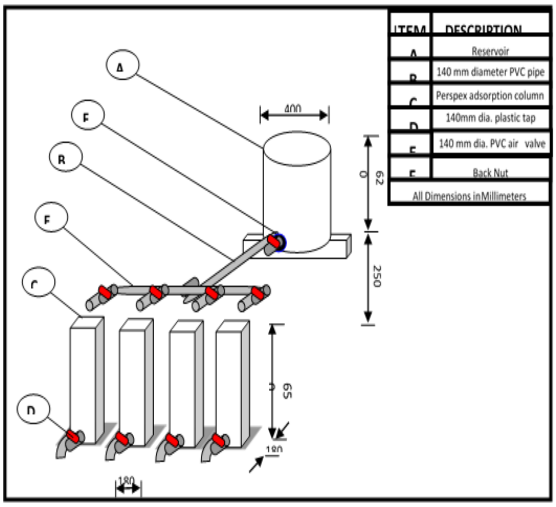


***Figure 3:** Filtration and adsorption-filtration setup*

Turbidity of water samples were used as a measure of the filter medium straining efficiency and was measured using a turbidimeter (HACH-2100) while the escaped particles were analysed by particle diameter measuring meter (LATS-1) as suggested by ASTM (2007). Indices, which were considered for evaluation of filter efficiency, were the EPN (escaped particle number) and the PI (particle index). The PI was calculated by multiplying the EPN with particle diameter (PD) as suggested by Gholikandi *et al.* (2012).

After the hydrogen peroxide oxidation process (Table 1) it was observed that the concentration of cyanide dropped by 0.34 mg/l which signified an 85% reduction, this may have been principally due to cyanide destruction process which converts cyanide to cyanate as stated by *Young and Jordan (1995). A*ll other physico-chemical parameters present were also reduced this may have been due to a number of reactions such as peroxide stabilization/ decomposition and metal ion precipitation as observed by different authors, Haber and

Table 1: Comparison of initial and final water quality of the treatment lines with FEPA/NESREA standards and separation of significant means within measured parameters using Duncan's Multiple Range Tests

S/N	Parameter*	FEPA/NESREA Standard		O	A	B	Final Water Quality?				P-value
		Water	Land				C_0	C_1	C_2	C_3	
1	Colour^m	7	-	3.12	2.33	3.13	2.03^a	1.67^b	$1.50^{b,c}$	1.33^c	0.0011
2	Mg^{2+}	200	-	45.00	33.83	30.17	29.33^a	26.6^a	23.33^b	23.33^b	0.0024
3	CN^-	0.1	-	0.40	0.06	0.02	0.02^a	0.02^a	0.00^b	0.00^b	<0.0001
4	SO_4^{2-}	500	1,000	15.3	7.42	4.65	3.89^a	2.37^b	2.17^c	2.13^c	<0.0001
5	NO^{3-}	20	-	1.35	0.75	0.45	0.32^a	$0.28^{a,b}$	$0.22^{b,c}$	0.18^c	0.0336
6	Fe^{2+}	20	-	0.85	0.62	0.57	0.50^a	0.50^a	0.47^a	0.43^a	0.2886
7	PO_4^{3-}	5	10	0.97	0.53	0.33	0.23^a	$0.17^{a,b}$	$0.17^{a,b}$	0.13^c	0.0375
8	Mn^{2+}	5	-	0.05	0.03	0.02	0.02^a	$0.02^{a,b}$	$0.02^{a,b}$	0.02^b	0.0896
9	Cl^-	600	-	36.45	21.82	18.28	17.37^a	15.47^b	14.68^c	14.38^c	<0.0001
10	Cd^{2+}	< 1	-	0.04	0.02	0.02	0.02^a	0.02^a	0.01^b	0.01^b	0.007
11	Hg^{2+}	0.05	-	0.00	0.00	0.00	0.00^a	0.00^a	0.00^a	0.00^a	--
12	Ni^{2+}	< 1	-	0.04	0.02	0.02	0.01^a	0.01^a	0.01^a	0.01^a	--
13	Ca^{2+}	200	-	250.67	82.00	73.67	74.33^a	$72.00^{a,b}$	$71.50^{a,b}$	69.67^b	0.0676
14	Zn^{2+}	< 1	-	0.82	0.52	0.43	0.37^a	0.37^a	0.37^a	0.30^a	0.2424
15	Phenol	0.2	-	0.09	0.01	0.00	0.00^a	0.00^a	0.00^a	0.00^a	--
16	TDS	2,000	200	612.50	759.56	863.67	603.56^a	198.22^b	193.00^c	107.67^d	<0.0001
17	TSS	30	-	2318.44	2166.33	1972.11	1263.33^a	1746.67^b	1716.67^c	1668.33^d	<0.0001
18	Coliform Count^n	400	500	36333.30	12666.70	2466.70	323.33^a	450.00^a	730.00^b	753.00^b	0.0005
19	BOD_5	50	500	111.33	76.89	67.33	40.44^a	24.00^b	16.11^c	16.89^c	<0.0001

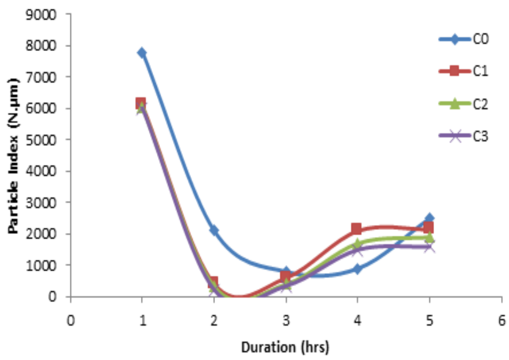
m Lovibond Units
n Most Probable Number MPN)/100 ml
* All units mg/l unless otherwise stated
? Superscripts with the same letters along the row are not statistically different at *p* 0.05.

O = Raw wastewater, A =Peroxide oxidised wastewater, B=Aerated wastewater,
C_0 = Carbon depth 0 cm, C_1 = Carbon depth 5cm, C_2 = Carbon depth 10 cm,
C_3 = Carbon depth 15cm

Weiss (1934); Baciocchi *et al.* (2004); Mecozzi *et al.* (2006); Badmus *et al.*, (2007); Omotosho and Amori (2015) and Dongwook *et al.* (2015). Biological Oxygen Demand was also observed to have reduced by 31.44 mg/l this may also have been due to the effect of release of oxygen during the peroxide decomposition process leading to increase in Dissolved Oxygen (Sindhi and Mehta, 2014) content which is usually in inverse proportion to BOD. The coliform count value in the water was also observed to have reduced after the process. This trend may have been due to coliform inactivation by hydrogen peroxide as observed by Vargas *et al.* (2013). The aeration process was observed to have no effect on the heavy metal (mercury, cadmium and nickel) content of the wastewater. The concentrations of other physico-chemical parameters were however observed to have reduced after the aeration process. BOD_5 level was also observed to have further reduced after the process. This reduction may have been caused by increase in dissolved oxygen resulting from agitation of the wastewater which would have caused trapping of atmospheric oxygen in the water as the process went on this reduction in BOD_5 values after aeration process was also observed by Lalwani and Devadasan (2013). The coliform count was observed to have dropped by 10,200 MPN/100 ml after the wastewater passed through the aeration process this trend was also observed by Radhi and Borghei (2017) and this may have been due to elimination of weak coliform matter by physical agitation.

Concentration of physico-chemical parameters in the effluent drawn after the filtration process (C_0) as revealed in Table 1 shows that all parameters were below FEPA/NESREA's upper limits for discharge to land and water course with the exception of TSS. This reveals that there is a need for inclusion of a sedimentation tank at the end of the treatment line. The BOD_5 and coliform count levels were also within limits of the effluent standard. Analysis of effluent drawn from the adsorption-filter columns (C_1, C_2 and C_3) reveals that similar to the filtration process, the concentration of all the physico-chemical parameters were also below the FEPA/NESREA's discharge limits for land and water with the exception of TSS. However the coliform count level observed in the 10 and 15 cm carbon depth columns (C_2 and C_3) were above FEPA/NESREA's upper limits for discharge to land and water. The result obtained from the 5 cm carbon depth column (C_1) was within the limit for land application but above the limit for water discharge. This reveals that only the C_1 column could be considered for irrigation. The trend in coliform count as observed in the adsorption-filter processes could have been due to the moisture retention capacity of the carbon contents of the columns which offered favourable environment for microbial culturing during periods of dormancy. The BOD_5 concentration of effluents from all the adsorption-filters were below FEPA/NESREA's standard for discharge to land and water. It was also noticed that the BOD_5 reduction increased with increase in carbon depth.

The particle index (P.I.) comparison graph (Figure 4) revealed that dual media filters (C_1, C_2 and C_3) exhibited a very sharp reduction to their respective lowest values over the first 1 hour of filter operation before the index began to rise back their respective equilibrium positions this noticed trend was different for the sand filter column which exhibited a continuous decrease in P.I. over the first 3 hours before picking up to a P.I. value which was higher than what was obtainable in the dual filter media. The trend noticed was similar to what was observed by Gholikandi *et al.* (2012), however for this system the quick response and stabilisation time may have been due to the effect of carbon particle adsorption within the filter medium thus improving the filter medium efficiency. In summary it can be deduced that the adsorption-filters could offer a viable option of treatment if sedimentation and chlorination treatment lines were incorporated to the setup.



The *p*-value obtained from ANOVA showed that the effect of carbon depth on concentration for considered parameters were not significant (p 0.05) for iron, manganese, calcium and zinc only while all others were significant. The separation of effluent parameter means done by DMRT revealed that the mean of values from the four columns were not significantly ($p > 0.05$) different for iron, manganese, mercury, nickel, zinc and phenol ions while those for colour, nitrate, total dissolved solids and total suspended solids were all significantly different. All other parameters however had two or more parameters sharing mean values that were grouped as not being significantly different.

Conclusions

The treatment of effluent from cassava processing was successfully carried out using the treatment lines combining peroxide oxidation, aeration, filtration and adsorption-filtration processes. The result showed that treatment lines were able to bring BOD_5 as well as considered physico-chemical parameters below the upper limits for discharge to water and land with the exception of TSS. The C_2 and C_3 treatment lines were however unable to reduce Total coliform count to acceptable range for discharge to land and water. Effluent from C_1 treatment line was within the limit for discharge to land but above that for discharge to water course. The C_0 (without carbon) treatment line was adequate in controlling the coliform count to range below the limit for land and water discharge. The treatment line C_0 was the most effective in treating the wastewater. It can therefore be concluded that the treatment line offered the most viable option in terms of cassava processing wastewater recycle and reuse and could serve as an asset for agricultural production especially in areas with limited water supply.

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