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EFFICIENCY OF A DEVELOPED CASSAVA WASTEWATER TREATMENT SYSTEM (CWTS) BASED ON PHYSICO-CHEMICAL VARIABLES STUDIED

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Abstract

The study was designed to evaluate the efficiency of a developed Cassava Wastewater Treatment System (CWTS) based on the physico-chemical variables studied. The CWTS contained a single rectangular column partitioned into four compartments with different filter materials. The turbidity and pH of the effluent were measured, and the readings were sent to the ESP-32 micro controller (Arduino) for display on the Liquid Crystal Display (LCD) at column 3. If the pH and turbidity readings were as high as they were in this work, the pump was activated and recirculated the effluents to column one until the third consecutive trial experiments, when it was observed that the turbidity and pH had been substantially reduced and the pump was off. The effluent was released through a drainage system at the bottom of the column. The Removal Efficiency (RE) of the CTWS was determined, and the MATLAB statistical program was used to optimize the conditions. The REs were as follows: the turbidity (25%), pH (56%), total suspended solids (TSS) (30%), and chemical oxygen demand (COD) (43%).

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Key words

- Cassava,
- Wastewater,
- Removal efficiency,
- Variables,
- Treatment method.

1 INTRODUCTION

Statistics have shown that the volume of cassava wastewater generated from the cassava (Manihot esculenta Crantz) processing industries is appalling, and it is often poorly managed (Balagopalan and Rajalekshmy 1998). This wastewater is characterized by hydrogen cyanide, which is considered a very toxic substance, as it is high in the chemical oxygen demand (COD) and biochemical oxygen demand (BOD), floatable solids, and odiferous substances (Kaewkannetra et al., 2009; Gao et al., 2012). The detectable level of cyanide, for example, depends on the varieties of cassava, which have been found to range from 10.40 to 274 mg/l. According to (ASEAN, 2023) the permissible levels from cassava wastewater for the pH, COD, BOD, and total dissolved solids (TDS) were reported as 5.5 - 9.0, 400 - 600 mg/L,150 - 5,000 mg/L, respectively. This level of cyanide reported in the cassava wastewater is enough to cause an ecological imbalance in aquatic resources if it is discharged untreated into water bodies as is commonly done. Several treatment methods for cassava wastewater have been reported in the literature. Ugwu and Agunwamba (2012) used an alkali treatment, while Potivichayanon et al., 2020, Sorgatto et al., 2021) used a biological treatment, which might be unconnected to the high organic contents of cassava wastewater. The optimization of a model treatment method for cassava wastewater was carried out by (Ibeje and Onukwugha, 2021). It is clear from the foregoing that the release of untreated cassava wastewater is deleterious to the quality of the receiving water bodies. The challenge of building a portable wastewater treatment, which is closely located to the cassava processing industry, is now achieving momentum. A multi-stage treatment method based on a continuous batch system has been used to treat several types of domestic and industrial wastewater (Atojunere and Ogedengbe, 2019; Atojunere and Ogundipe, 2022). Coagulation and flocculation using Moringa oleifera seeds and aerobic, anaerobic, and facultative ponds have been reported to be effective methods for cassava wastewater treatment (Trevisana et al., 2019). Different unit treatment methods have been tested for cassava wastewater treatment (Oghenejoboh, 2015; Rodrigues et al., 2021; Acchar and Silva, 2021; Schmidt et al., 2021; Walthier et al., 2019; Bezerra et al., 2017; Almenda and Moresco, 2021). This process is unlike the conventional treatment system which is complex, fixed and expensive; the portable wastewater treatment device is rather simple, detachable, and efficient. Some portable wastewater treatment systems for decontamination of bitumen-polluted water as well as cassava wastewater are now in use on a pilot scale (Atojunere, 2024, Atojunere and Ogedengbe, 2019; Atojunere et al., 2018). The current study is designed, however, to showcase the modification of an existing wastewater treatment system using filtration and using different media in connection with the recirculation device.

2 MATERIALS AND METHODS

Previous works by (Atojunere and Ogedengbe, 2010; Atojunere, 2021; Atojunere and Amiegbe, 2024) on the development of treatment systems for wastewater decontamination were thoroughly reviewed, and some of their findings were incorporated. Theoretical studies were important considerations for the present study in order to improve the quality of the final cassava wastewater effluent and for its optimization. The construction of the Cassava Wastewater Treatment System (CWTS) was carried out in a laboratory, and the assembly was done with the necessary calibration of the pH and turbidity sensors. The material for the construction of the Cassava Wastewater Treatment System (CWTS) is itemized in Table 1. The construction of the control box, the columns of the containments, and the entire CWTS, including the coding and installation of the hardware and software components. were carried out according to their standard. The cassava wastewater for the treatment trial was collected at the Baiyeku Processing Factory, Ikorodu, in the city of Lagos, Nigeria. The concentrations of the variables studied, including the pH, CN, BOD, COD, TDS, and turbidity, and were determined before and after passing through the CTWS by standard procedures both in-situ and in the laboratory (Okunade and Adekalu, 2013; Fashanu et al., 2019; WHO, 2019). The physico-chemical parameters obtained from the CWTS were compared with the standards (Morgan, 1990; Tchobanoglous et al., 1991; Lima et al., 2009).

2.1 Development of the CWTS

The height of the CWTS was 3 ft. (0.91 m), and the base was 220 mm x 220 mm. It consisted of four columns (1 to 4) with a storage capacity of 5 liters each. They were placed in vertical fixed beds, where the cassava wastewater was applied to the surface of three (3) different filter materials, namely, porous media, cotton wool, and fabric cotton. A control unit was attached. The effluent drained vertically through the media towards the final drainage system in the bottom of column 4. There were three (3) squared, drilled perforate plates inserted, one per each column of 220 mm × 220 mm with 256 (1-mm diameter) holes. They were glued to the columns to form a fixed bed midway at 0. 375 ft depth except for column 4. The drainage pipe of each column was located at 0.16 ft (60 mm) dead storage and drained the effluent to the next stage, when their taps were opened. The fixed bed allowed the filtrates to pass to the base of each column through the perforated base. The taps controlled the rate of the flow of the inlet and outlet in the columns. The treatment process involved intermittent short-term loading and a detention period, when the influent percolated through the unsaturated media. The forward flow from stages 1 to 4 was due to gravity by the opening and closing of the taps on the drainage pipes attached to each column. At stages 1 to 3, the influent was held for 3, 5, and 7 minutes and longer at column 4. The control unit box consisted of the electronic casing which housed the Arduino microcontroller, the relay optocoupler module, the turbidity meter, and a direct current (DC) pump. An integrated development environment (IDE) was used to program the relay and pump in the box, and the calibration of the turbidity sensors was performed in the C++ programming language.

Tab. 1 *List of materials for the construction of the CWTS*

S/N	Materials	Quantity	Purpose
1	Acrylic glass	20 ft., 5 mm thick	Building of the CWTS treatment columns
2	Plastic Pipe Polyvinyl chloride (PVC)	(5), ½ inches 2 mm thickness 10 m long	To build the cassava wastewater drainage system inlet and outlet
3	Chiffon fabric cotton	5 yards,59-in. diameter	Guide to enable the solid particles to pass with the filtrate
4	control gate valves	4	To open and close the inlet and outlet
5	PVC elbow 45-degree bends	6	pipe accessories required at pipe joints
6	PVC sockets ½-inch external thread	10, 2-inches by 2 inches,	Connecting pipe accessories
7	5-V Direct Current (DC) grove Turbidity (meter)	1	For measuring the turbidity of the cassava wastewater

8	6-V Relay Module with Optocoupler Relay Output (DC)	4	Input interface for electronic devices
9	12-V,pneumatic diaphragm Water Pump Motor R365	1	Pumping treated cassava wastewater during recirculation
10	Liquid Crystal Display (LCD)	1	To display pH and turbidity readings
11	Software-Arduino IDE, Electrical Power source (AC),	2	Connecting software to hardware components in the CWTS
12	Electronic Casing	1	Provide protection to electronic hardware’s
13	20000 mAh power bank,	1	standby power supply
14	wastewater sample bottles	10	Samplings of treated cassava wastewater for analyses
15	silicon gum and jumper wire pack	2, (1) roll	Joining components together and to make the CWTS watertight

The CTWS operational condition during testing and its algorithm is shown in Figures 1 and 2. After the stage-by-stage treatment, the turbidity level of the effluent in the column 4 water was automatically determined by the turbidity probe inserted in column 3; the reading was sent to the Arduino ESP-32 micro controller and was displayed on the LCD. The turbidity of the cassava wastewater could be high as 2,400 Nephelometric Turbidity Units (NTU). If the reading was as high as it was in this work (2000 > 1500 > 1000 > 500 > 400 NTU), the pump inside the control unit was activated and recirculated the effluent to stage 1, until many runs, when it was observed that the turbidity level had been substantially reduced and that the pump had turned off. The threshold was 400 NTU. The final effluent was released through the drainage pipe at the bottom of the CWTS column 4 when tap 4 was opened at the time the pump was turned off. The pump operation is automated; it recirculates the treated cassava wastewater when the set threshold for turbidity is not met. The flow rates of the cassava wastewater through media during treatment was calculated (Equations 1,2 and 3). This is the frequency of the average residue removal rates on the filters with respect to the load or flow volume. The final turbidity values of the effluent were calculated from Equation 4. The dissolved solids that were present in the filtrate can be removed by using activated charcoal (Atojunere et al. 2019, Atojunere et al., 2019). The experiment was repeated for 3 more trials. The literature shows that activated charcoal has a removal efficiency of toxic substances of 83-93% and 95-99% for arsenic and cyanide respectively. The removal efficiency (RE) shown in Equation 5 of the CWTS was calculated based on the values of the physico-chemical parameters studied. The cyanide (CN), pH, COD, TDS and turbidity (NTU) were determined in-situ and in the laboratory. The filter media were replaced after 3 runs to avoid clogging and to prevent the growth of the trapped microorganisms. The spent filter media were handled aseptically before disposal. The plotting of the data was carried using MATLAB as shown in Figures 3a and 3b respectively.

$$\text{Porous media } \frac{volume\ of\ wastewater}{time\ taken} = \frac{0.005m^3}{420s} = 1.2\times 10^{-5} m^3/s \quad (1)$$

$$\text{Cotton wool } \frac{volume\ of\ wastewater}{time\ taken} = \frac{0.005m^3}{300s} = 1.6\times 10^{-5} m^3/s \quad (2)$$

$$\text{Fabric cotton } \frac{volume\ of\ wastewater}{time\ taken} = \frac{0.005m^3}{180s} = 2.7\times 10^{-5} m^3/s \quad (3)$$

$$\frac{\text{Final turbity level}}{\text{Initial turbidity level}} \times 100 \quad (4)$$

$$\text{RE} = (\text{Initial} - \text{final}) \times 100 \quad (5)$$

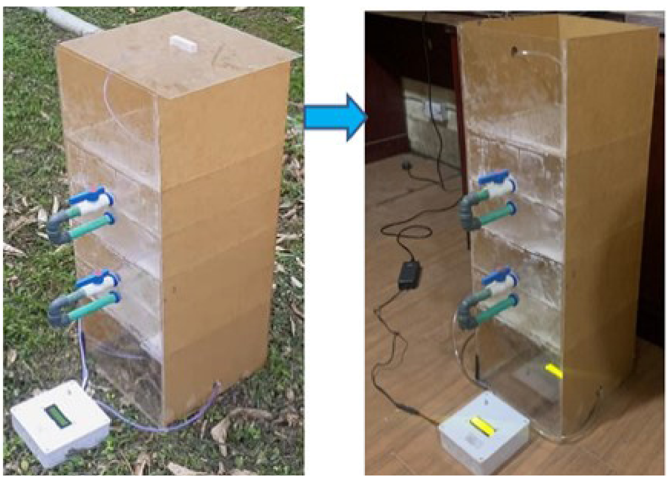

Fig. 1 The loading and unloaded condition of the CWTS during testing with the cassava wastewater

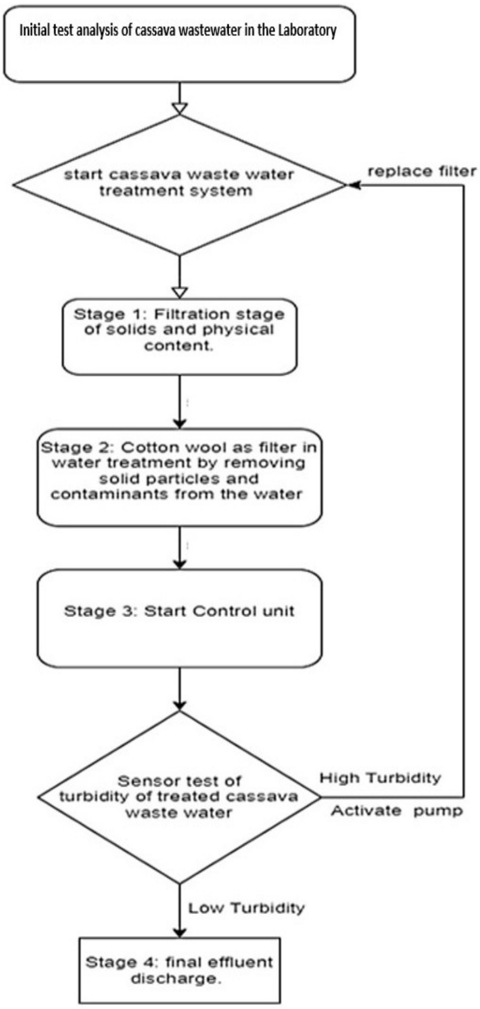

Fig. 2 *The step - by - step algorithm of the CWTS during the cassava wastewater treatment*

3 RESULTS AND DISCUSSIONS

The results of the physio-chemical parameters of the treated cassava wastewater during and after treatment with the CWTS are shown in Tab. 2 along with some data for comparison with the permissible levels. No chemical adjustment was made during the treatment of the cassava wastewater with the developed CWTS, which formed the basis of the comparison; however, this was not the case if there was a pH adjustment. The addition of tannin and coagulant was carried out (Oliveira et al., 2001). A 91% reduction in some physico-chemical parameters studied occurred with the addition of the tannin to the coagulation treatment method for the cassava wastewater (Oliveira et al., 2001), while an 86% reduction was reported with the addition of aluminum polychoride (50mg/L) to the unit treatment processes (Hess,1962).

The present study utilized low-cost adsorbent materials along with different unit processes for better results from the developed CWTS. The pH of the final effluent in the present study was 4.9 to 8.0, and the removal rate was 56%. The pH in the basic medium was supposedly to have significantly increased precipitation of the suspended solids, which allowed them to settle. The possibility that most solids were in the suspension cannot be totally ruled out. For the pH removal alone, the CWTS's removal efficiency for the pH in the present study on the treated wastewater was 56%. The RE of the 56% removal rate was an improvement over what has been reported at 33.4% (Atojunere and Ogundipe,2022). However, there was a consistency in the pH reduction in the two studies with variations that ranged from 38 to 56%. This is perhaps due to differences in the cassava species that the factory processed at the time of the sample collection. This finding is in agreement with work by (Kaewkannetra et al., 2009), which stated that the detectable level of the physico-chemical parameters before and after treatment could be dependent on the cassava varieties.

The RE of the CWTS for the TSS of the final effluent in the present study was 45% compared to 42.3% (Atojunere and Ogundipe, 2022). This was still considered to be a low RE; however, the increased removal of the physico-chemical parameter studied is noticeably attributable to the ability of the

Tab. 2 *The step - by - step algorithm of the CWTS during the cassava wastewater treatment*

Parameters	Present Study	RE	Remark	Atojunere & Ogundipe (2022)	RE	Remark	Morgan (1990)	WHO (2004)
pH	4.9 - 8	56	Higher	4.5 - 6.0	33.4	Lower	6-8	6-8
TSS	6000 - 6140	45	Higher	38	42.3	Lower	500	2000
COD	53.48 - 55.94	47	Higher	140.03 – 800	43.4	Lower	-	60
Turbidity	434 - 585	56	Higher	6 – 40	25.2	Lower	-	25
Cyanide	15 - 70.21	40	Higher	10.5 - 50.17	38.3	Lower	-	-

adsorbent media to trap impurities as the cassava wastewater passes through the fixed beds. The flow rates were another factor for the increased RE, which determined the movement of the influent from one column to another, and which significantly contributed to the high effluent quality obtained. In addition, the RE of the 47% removal rate was an improvement over the results reported by (Atojunere and Ogundipe, 2022), which was 42.3%. The clogging of the filter was improved upon through recirculation, although some solids, especially the dissolved ones, percolated through the media to the final stage. The smaller-diameter perforated base also hindered the movement of free particles, but this might not be adequate to stop their total migration to column 4 as noted in this work. This improvement of the ability of the CTWS to trap more solids compared to Atojunere and Ogundipe, 2022, was that sedimentation was carried out prior to the release of the influent at stage 1, which reduced the organic loading that the starch might have added to the filter media. The RE of the CWTS for COD of the present study was 47% and an improvement on (Atojunere and Ogundipe, 2022), which was reported at 43.4%. The was an indication that CTWS was effective in handling cassava wastewater even with its high organic load. This is still considered as a low reduction. Nevertheless, the lower removal rate agreed with the work by (Xu et al., 2005), which stated that most organic materials in wastewater are either in a dissolved state or colloidal suspension, so that a multiple unit wastewater treatment process may produce better results over single filtration. However, the recirculation stage in the present study of the final effluent created more contact time and an oxygen exchange, which was responsible for the observed low odour level, which is not common with cassava wastewater. The reduction of the organic loading at stage 1 reduced stress on the CTWS filters as more solids that required more oxygen (increased COD level) had been removed during the pre-treatment.

The RE of the turbidity was 56%. The RE was an improvement over (Atojunere and Ogundipe, 2022), which was reported as 25.2 %. After 3 runs, as was earlier reported, the turbidity level of the final effluent was significantly reduced. The more the air flowed, and the longer the contact time for the wastewater to settle, the better the final effluent quality from the CWTS. The turbidity level was reduced from 585 to 434 NTU (56%). The RE for cyanide (CN) of the final effluent was 40 %. The results indicated that the CWTS was able to reduce the cyanide by 2 % without any chemical adjustment. While this was not the best, considering the toxicity of the cyanide with an RE of 40 %, it was an improvement over the 38.3% reported by Atojunere and Ogundipe, 2022). The RE level with a chemical adjustment might not be significant in this work. This is because at an earlier time, Xu et al., 2005, reported that there was no significant difference when the chemical adjustment was applied to the cassava wastewater treatment. The trend of the REs (Table 2) for the present work and earlier work by Atojunere and Ogundipe (2022) and the physico-chemical variables, i.e., the turbidity, pH, TDS, cyanide and COD studied, were higher in the former than the latter. The improvements were due to the modification in the components design (more holes of smaller diameters drilled on the fixed bed plates), adsorbent materials, adjustable flow rates, higher contact time, greater oxygen exchange, and frequent filter replacement. The response surface, the radar plot of the physico-chemical parameters studied for the three runs, and the REs of the CWTS was presented in Figure 3. There was an increasing RE trend of the CTWS; cyanide level 40 % < TDS 45% < COD 47% < turbidity and pH 56 % respectively.

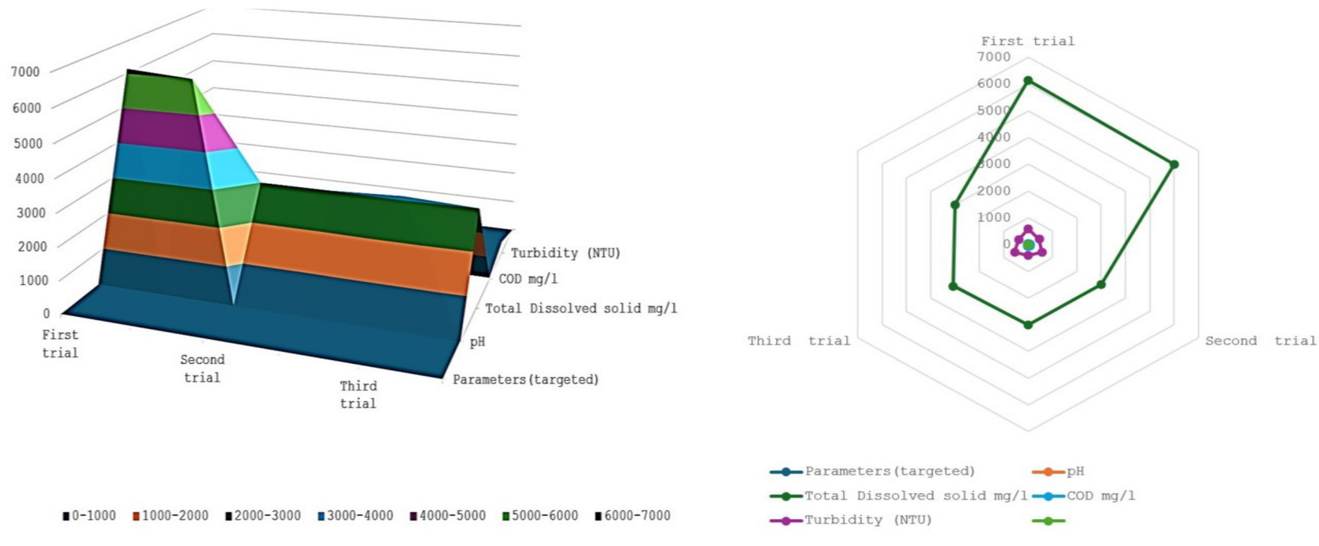

Fig. 3a through 3b. (a) Response Surface (b) Radar plot for removal efficiency of CTWS.

4 CONCLUSION

The removal efficiencies of the Cassava Wastewater Treatment System (CTWS) for the variables studied were turbidity (56%), pH (56%), total suspended solids (45%), COD (47%), and CN (40%). The high treatability was partly because of the recirculation process, which allowed for more treatment time and aeration inside the CWTS. Furthermore, the CTWS developed optimized its working operations, which probably resulted in better overall treatment of the cassava wastewater reported.

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