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The Cassava Wastewater Treatment System with and without Recirculation – Challenge and Prospect

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ABSTRACT

The volume of wastewater produced during the secondary processing of cassava into cassava products is significant. This growing concern is not intended to undermine the importance of cassava as a staple food in many countries; instead, it is linked to the way wastewater is handled, which is considered deficient. This review is based on secondary data gathered from over 50 studies published between 2005 and 2025 on different treatment methods for cassava wastewater. It compared the Removal Efficiency (RE) of two existing Cassava Wastewater Treatment Systems: one with Recirculation (CWTS-R) and the other without Recirculation (CWTS-WR). The REs were based on four studied physicochemical parameters: Suspended Solids (SS), COD, turbidity, and cyanide. The trend for the REs was: pH 56 > 33.4; SS 45 > 42.3; COD 47 > 43.2; Turbidity 56 > 25.2; and Cyanide 40 > 38.3 for CWTS-R and CWTS-WR. The data obtained revealed that the REs for the CWTS-R were higher across all studied physiochemical parameters than those for the CWTS-WR. The contaminants removal abilities of the CWTS-R and CWTS-WR were significantly different. The increase in the REs might not be unrelated to the addition of a pump that redirects cassava wastewater back to the starting treatment points when the set threshold limits for these parameters are exceeded. Optimizing the operations of the existing CWTS-R and CWTS-WR is recommended to improve efficiency.

1. INTRODUCTION

Cassava (*Manihot esculenta*) is a tuber crop indigenous to South American countries and is gradually spreading to many others [1]. It is considered one of the top five crops in the world, known for its nutritional value and used as a staple food or as raw material by many industries [2]. However, the secondary processing of cassava into products such as starch and cassava flour generates a large volume of wastewater, which is reportedly poorly managed by local industries, ending up in waste pits, landfills, impoundments, and streams and rivers without proper treatment [3]. These treatment methods are deficient given the characteristics of cassava wastewater, which include high Biochemical Oxygen Demand (BOD), starch, turbidity, and cyanide, among others. Cassava wastewater is the liquid residue produced after a mechanically crushed cassava tuber is dewatered [4]. Cassava wastewater is characterized by floatable solids, high organic content, high BOD and Chemical Oxygen Demand (COD), and a substantial amount of toxic substances, such as cyanide (CN). The high toxicity of wastewater generated during secondary processing of cassava might not be unconnected to enzymatic metabolism during fermentation, which produced toxic end products [5]. There is a possibility that leachate from the landfill, stored with cassava wastewater, percolates into the subsurface environment and impairs its water quality. While some of these contaminants in cassava wastewater are harmless in themselves, the presence of cyanide CN is of public health concern due to its toxicity, known for causing acute disorder both in humans and animals if ingested [6]. Therefore, the release of such untreated wastewater into the environment is a disaster in the offing, which could endanger human and animal lives through the ingestion of contaminated food and water. More so, cyanide is an unstable chemical that can exist in more than one chemical form. The transformed cyanide is considered more toxic; for instance, cyanide could hydrolyze to a harmful form of hydrocyanic acid [7]. A high level of hydrocyanic acid has

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reportedly been detected in a sample of fish caught from rivers receiving large volumes of untreated cassava wastewater [8]. Nevertheless, there is a good side to cassava wastewater; many scholarly works [9]-[22] have reported varying concentrations of macro and micro nutrients in cassava wastewater. They were nitrogen and potassium at 3.3 and 5.9 g/l, respectively, while magnesium, phosphorus, calcium, iron, and sodium were up to 0.62, 0.74, 0.38, 0.11, and 0.74 g/l, respectively, as presented in Tables 1 and 2. The cassava wastewater samples were taken from a local factory that processed cassava into starch and flour. The presence of nutrients in cassava wastewater suggested a possibility of harnessing these essential nutrients for value addition in agriculture, such as organic farming, fish farming, and aquaponics. Despite these possibilities, the report of cyanide CN level in the tested cassava wastewater samples is disturbing, considering the varied levels between 0.002 and 0.09 g/l. The objective of this review is to identify current methods for treating cassava wastewater and to suggest technical solutions for addressing future challenges.

Table 1. The nutrient composition(g/l) of some cassava wastewater samples taken from flour and starch industries

P	N	Na	K	Ca	Mg	Cu	Fe	Mn	Zn
0.38	0.88	NA	3.9	2.3	0.57	NA	0.093	0.0002	NA
0.74	0.98	0.46	1.97	0.24	0.36	0.02	0.01	0.003	0.02
0.67	1.59	0.126	5.9	0.38	1.52	NA	NA	NA	NA
0.28	NA	0.74	4.79	0.24	1.59	NA	NA	NA	NA
0.4	3.3	NA	2.8	0.2	0.6	0.01	0.01	0.0008	0.001
0.35	1.54	0.44	2.94	0.2	0.38	0.0005	0.022	0.004	0.005
0.03	0.95	NA	0.35	0.03	0.01	0.0004	NA	NA	NA
0.16	1.14	NA	0.95	0.02	0.007	0.0002	NA	NA	NA
0.08	0.95	NA	0.46	0.02	0.01	0.0002	NA	NA	NA
0.13	1.12	NA	1.45	0.09	0.21	0.009	0.11	0.001	0.002

NA: Not Analyzed

Table 2. The characteristics of cassava wastewater(mg/l) sample from flour and starch industries

Industries	pH	COD	BOD	TA	VFA	TN	TP	TS	CN
Flour	4.6	65	NA	3.41	NA	1.73	0.7	58	NA
	4.5	141	NA	1.62	0.01	2.05	0.27	NA	NA
	6.63	14.3	12.21	NA	NA	0.36	0.04	0.007	0.012
	4	15.7	10.3	NA	NA	NA	NA	3.45	0.04
	5.1	89.75	NA	NA	NA	NA	NA	NA	0.09
	6.2	79.48	NA	NA	NA	NA	NA	NA	0.02
	6.2	92.44	NA	NA	NA	NA	NA	NA	0.07
Starch	NA	8	6	NA	NA	0.17	0.04	6.02	<0.05
	4.9	11	NA	NA	NA	0.53	0.09	NA	0.002
	4.5	16	8	NA	NA	NA	NA	14.34	NA
	4.8	2	2	NA	0.07	0.17	0.09	7.67	0.023
	5.7	10	NA	0.21	NA	0.17	0.02	NA	NA
	4.8	2.24	1.45	NA	NA	0.02	0.09	7.66	0.023
	4.5	14.7	6	NA	NA	NA	NA	NA	0.005

Total Alkalinity TA, Volatile Fatty Acids VFA, Total Nitrogen TN, Total Solids TS, Total Cyanide g/l TCN, Total Phosphorous TP. This review is based on secondary data gathered from more than 50 studies published between 2005 and 2025 on different treatment methods for cassava wastewater. It compared the Removal Efficiency (RE) of two existing Cassava Wastewater Treatment Systems: one with Recirculation (CWTS-R) and the other without

Recirculation (CWTS-WR). Some scholarly works [23]-[62], on cassava wastewater that were thoroughly reviewed reported variation in the contaminants level present in some tested samples of cassava wastewater. Based on this review, the treatment methods employed for cassava wastewater were grouped into current and proposed technologies, as presented in Figure 1.

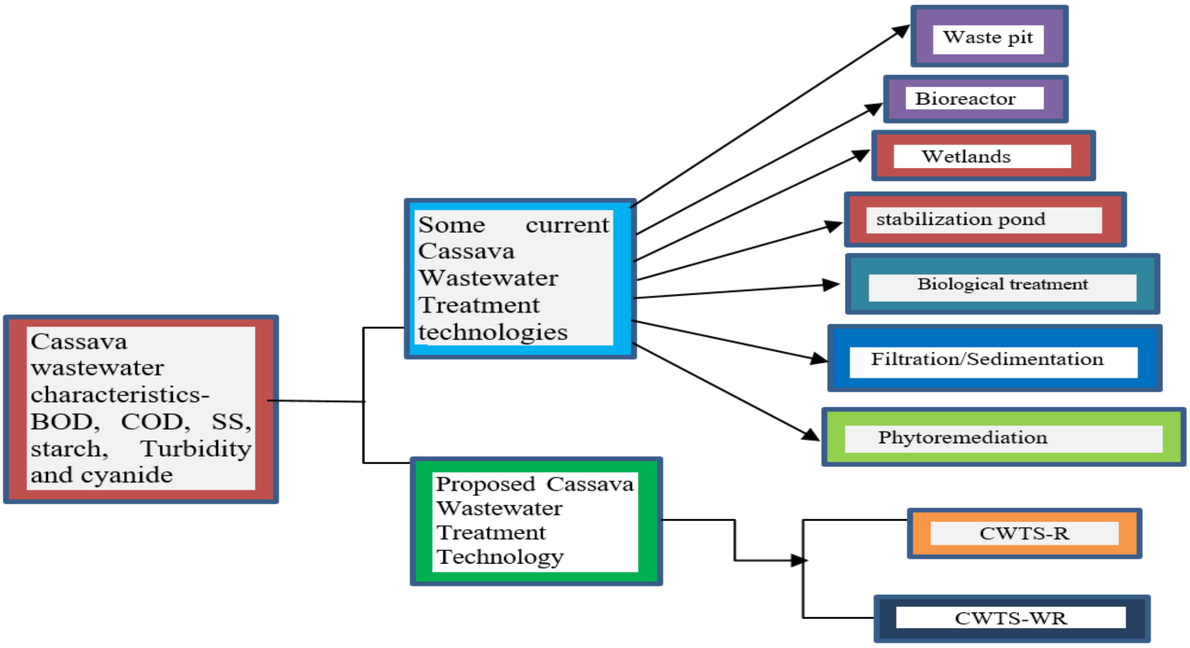

Figure 1. Some treatment methods for treating cassava wastewater, including the CWTS-R and CWTS-WR

2. The Operation of the Developed Cassava Wastewater Treatment System (CWTS)

The Cassava Wastewater Treatment System (CWTS) is a device that removes contaminants from cassava wastewater through a combination of one or more unit treatment processes [63][64].Two types were discussed, the Cassava Wastewater Treatment System with Recirculation (CWTS-R) and the Cassava Wastewater Treatment System without Recirculation CWTS-WR [65]. Both have been fabricated and tested on a pilot scale for treating cassava wastewater [66]. The objective of the systems was to combine one or more unit treatment processes, flotation, filtration, and sedimentation, to treat cassava wastewater before disposal. These systems were designed to work closely with the cassava processing factory. The CWTS-WR comprises four sets of rectangular filtration columns connected in series, and the cassava wastewater was released from a raised container 3 m high. The wastewater flow was controlled by gravity as it moved from one column to the next. There were 5 gate valves installed at intervals on the main pipe that control the release and withholding of the wastewater from one column to the other during treatment. The filter media for the CWTS-WR were cotton wool and chicken feathers, placed in cups in all columns except column 4, as shown in Figure 2. Samples from the treated wastewater were collected for physicochemical testing at each treatment stage, and pH, SS, turbidity, and cyanide were measured. To prevent clogging, spent media were replaced at intervals and properly disposed of to prevent secondary pollution [67]. The CWTS-WR component's parts were detachable, simple, easy to couple and repair, and the filter media are cheap and readily available for filter replacement. This is an alternative treatment method for cassava wastewater, as it is sustainable. On the one hand, the CWTS-R comprises 4 sets of rectangular filtration columns stacked vertically [68][69]. The cassava wastewater was released from column 1, and the flow from column 1 to 3 was controlled by gravity. In contrast, the recirculation of treated wastewater from column 3 to column 1 was driven by a 12-volt direct current pump connected to the system. Pipe fittings for gate valves controlled the release and withholding of wastewater from columns 1 to 3, and returned it as needed during treatment. The CWTS-R filter media were cotton wool placed in cups in all columns except column 4, as shown in Figure 3. The CWTS-R contained an electrical control box that housed the turbidity and pH sensors, the pump, a Liquid Crystal Display (LCD) display microcontroller powered by a 2000 mAh power bank. During treatment, the treated cassava wastewater from column 3 was recirculated to column 1 by the pump when the set-out permissible levels of pH and turbidity were not met. The pH and turbidity sensors were used to monitor the pH level and the relative clarity of the treated cassava wastewater in column 3, and the readings were reported to the microcontroller, which displayed them on the Liquid Crystal Display (LCD) of the control box. The decision to either recycle or discharge the treated cassava wastewater by the CWTS-R was based on the measured pH and turbidity values in the wastewater and the corresponding threshold values set in the system. If the pH and turbidity of the treated cassava wastewater were reported as high as it was for this case of the study under consideration, the pump recirculated the treated cassava wastewater to column 1. The entire treatment process was repeated until these thresholds were obtained. However, if the pH and turbidity were reported as below the threshold, the treated cassava wastewater was released through the drain Polyvinyl Chloride (PVC) pipe by manually opening tap 4. Fresh cassava wastewater was added to column 1, and the experiment was repeated. Some operational characteristics of CWTS-R and CWTS-WR were presented in Table 3. The Removal efficiency was calculated based on the four physicochemical parameters studied: pH, SS, turbidity, and cyanide. The trend for the REs was that pH 56 > 33.4; SS 45 > 42.3; COD 47 > 43.2; Turbidity 56 > 25.2; and Cyanide 40 > 38.3 for CWTS-R and CWTS-WR, as shown in Table 4. The REs of both systems were significantly different [3][4]. Their differences were attributed to three reasons highlighted below. First, the higher REs were not unrelated to proper aeration from the pump into the system, which introduced more free interstitial spaces for the solids present in the cassava wastewater undergoing treatment to settle during the recycled operation. Second, the smaller solids, especially the dissolved ones, combined to form a larger particle, which quickly settled after agitation from the pump, as fine air bubbles were sprayed when the treated cassava wastewater was reintroduced and pressurized back into the columns. Moreover, aeration has reduced odour levels associated with the final treated cassava wastewater. The third reason for the higher contaminant removal by CWTS-R over CWTS-WR was that some modifications in component design included more holes with smaller diameters drilled in the fixed-bed plates that housed the filter media, adjustable flow rates, higher contact time, and greater oxygen exchange. The comparison between the RE(s) for CWTS-WR and CWTS-R was described statistically in Figure 4. The costs of implementing the CWTS-R and CWTS-WR are manageable, with high acceptance in the rural areas where the local factories are located. The addition of AI, routing problems, and machine learning skills to optimize the current CWTS-R and CWTS-WR could improve contaminant removal [70].

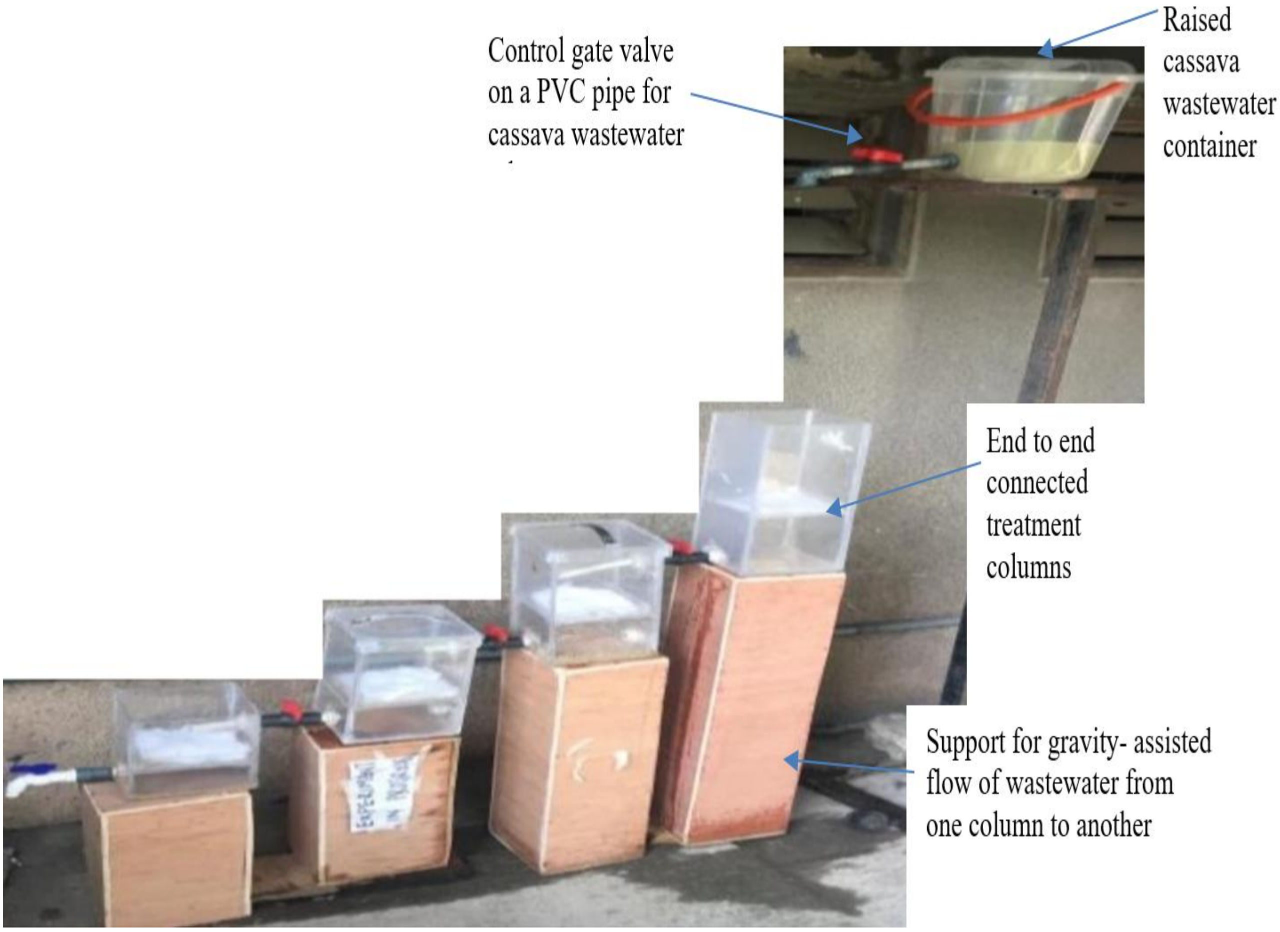

Figure 2. The Cassava Wastewater Treatment System without Recirculation (CWTS-WR) under loading conditions

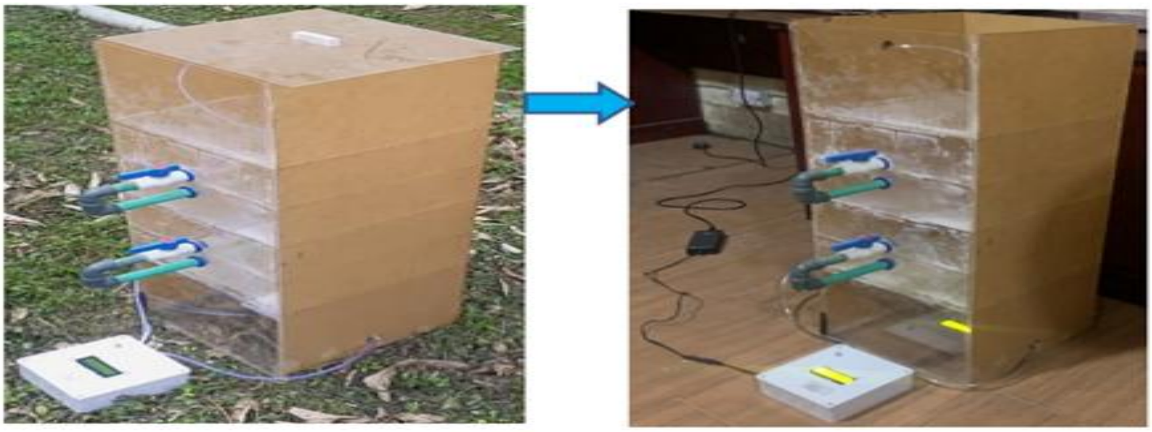

Figure 3. The Cassava Wastewater Treatment System with Recirculation (CWTSR) under loading conditions

Table 3. The operational characteristics of CWTS with or without recirculation

S/N	Operational parameters	CWTS-WR	CWTS-R
1	Sedimentation	There is a settling tank	There is a settling tank
2	influent	Cassava wastewater from the Cassava Processing factory	Cassava wastewater from the Cassava Processing factory
3	Wastewater characteristics	Foaming, solids with high organic properties, BOD, COD, odour, high turbidity, cyanide level	Foaming, solids with high organic properties, BOD, COD, odour, high turbidity, and cyanide level
5	Biological treatability	Yes	Yes
6	Unit treatment processes	Sedimentation, flotation, aeration, and filtration to remove floatable solids	Sedimentation, flotation, filtration to remove floatable solids, and aeration
7	Flow type	Gravitational	Gravitational assisted with a submersible pump for recirculation, the pump recirculates the effluent to stage 1 from 3 if the desired level of treatment is not achieved.
9	sorbent materials used	A ball of cotton wool and a chicken feather	ball of cotton wool only
10	Spent sorbents	Contain film of microorganisms. Aseptically handle before disposing of	Contain film of microorganisms, aseptically handle before disposing of
11	Physicochemical tests	Samples of treated effluent were collected at intervals for testing of pH, BOD, TSS, and turbidity.	Samples of treated water were collected at intervals for testing, while pH and turbidity were determined in situ using the monitoring sensor.
13	RE	Good Removal Efficiency.	Higher Removal Efficiency

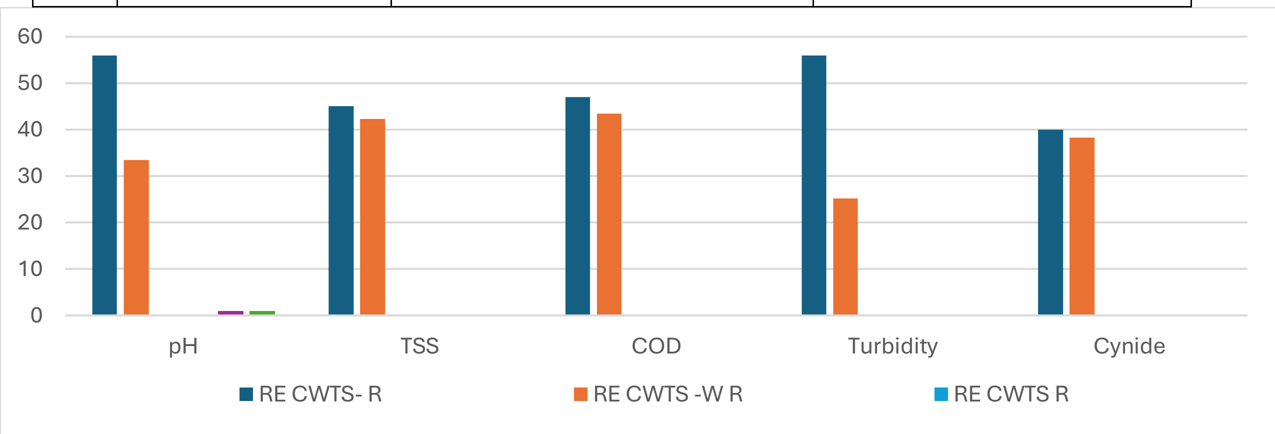

Figure 4. CWTS-R has higher REs than CWTS-WR on the physicochemical parameters studied

Table 4. Some comparisons between the Removal Efficiency of CWTS-R and CWTS-WR

Parameters	CWTS-WR	CWTS-R	CWTS-R	CWTS-WR	CWTS-R	CWTS-WR
pH	4.9 - 8	4.5-6.0	56	33.4	Higher	Lower
TSS	6000 - 6140	38	45	42.3	Higher	Lower
COD	53.48 - 55.94	140.03 - 800	47	43.4	Higher	Lower
Turbidity	434 - 585	6.00 - 40	56	25.2	Higher	Lower
Cyanide	15 - 70.21	10.5 - 50.17	40	38.3	Higher	Lower
SS	N/A	N/A	-	-	-	-

3. CONCLUSION

Biological treatments, landfills, phytoremediation, flocculation and coagulation, floatation, and filtration, among others, were found in the review of over 50 published articles as treatment methods for treating cassava wastewater. The review discussed the comparison of two existing Cassava Wastewater Treatment Systems with or without Recirculation CWTS-R and CWTS-WR based on their Removal Efficiency(RE) of four studied physicochemical parameters. The REs for both treatment systems were pH 56 > 33.4; SS 45 > 42.3; COD 47 > 43.2 > Turbidity 56 > 25.2, and cyanide 40 > 38.3 for CWTS-R and CWTS-WR. The REs of the CWTS-R were higher than the CWTS-WR in all the studied parameters: SS, COD, turbidity level, and cyanide. The paper suggested that the improvement in contaminants removal was connected with the addition of a pump to the CWTS-R, producing better removal efficiency over the gravity-based CWTS-WR. Therefore, it is recommended that optimization of the Cassava Wastewater Treatment System (CWTS) would be one of the viable options for treating cassava wastewater in the future.

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